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OF THE

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JOURNAL
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AMERICAN WELDING SOCIETY
ESTABLISHED 1919
JOURNAL

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CHANGE IN BY-LAWS

The By-Laws of the Society for the payment of dues have been changed to read, "All dues shall be payable in advance and shall cover a period of one year from the last day of the month in which a member joins."

A new section was added providing that with the approval of the Board of Directors the President may appoint any additional Committees for a denite stated purpose.

NOMINATING COMMITTEE APPOINTED

In accordance with the provision of the by-laws President T. F. Barton has appointed the following members of the Society as a Nominating Committee to nominate officers of the Society and nominate members to fill the vacancies on the Board of Directors: J. W. Owens, Chairman; H. A. Austin, J. C. Bennett, R. L. Brown, A. M Candy.

MEMBERSHIP CAMPAIGN

The officers of the Society are planning to launch an active membership campaign in the very near future in order to double the present membership of the Society. The campaign will be something of the order of the one conducted so successfully two years ago.

This is to advise every member of the Society to start in his missionary work in securing a member of a class equal to his own.

The American Welding Society made remarkable strides during the past year and deserves the support of every member. From the point of view of accomplishments we are doing as much as the larger societies with memberships totaling more than 10,000. Partially through the efforts of the Society and its various committees the application of welding during the past few years have nearly trebled. You no longer have to sell membership in the American Welding Society on the basis of prospective accomplishments as we can point with pride to past and present efforts. Perhaps you have some ideas as to how to successfully conduct the proposed membership campaign. Any suggestion for increasing membership will be welcomely received.

SECTION ACTIVITIES

Philadelphia

A business meeting of the Philadelphia Section was scheduled for December 17th at the Engineers Club at 8 P. M. The principal item on the calendar was a discussion of ways and means for promoting section activities.

Chicago

The December meeting of the Chicago Section was held on December 7th. Two papers were presented at this meeting, one by Mr. H. W. L. Porth of the Swift Refrigerator Transportation Company upon "Welding and Cutting in Connection With Car Repairs," and the other by Mr. E. S. Hurd of the Gibb Instrument Company upon "Resistance Welding." The next meeting of the Chicago Section will be held on January 4th. Mr. Clay W. Roberts of the Pennsylvania Railroad, will present an address on "Getting Results Economically by Arc Welding in Locomotive Work. He will be followed by a lecture on the manufacture of oxygen by Messrs D. B. McCloud and M. Keith Dunham. Both papers will be illustrated with lantern slides.

Pittsburgh

The January meeting of the Pittsburgh Section will be held on January 11th. Mr. H. S. Mann of the H. Kleinhaus Company, will present a paper on "Precision work by Electric Arc Welding"

New York

The January meeting of the New York Section will be held on January 8th at the Air Reduction Com-

pany plant in Jersey City. The program includes a demonstration of advantages of the Air Reduction Company's specially designed welding and cutting machine, the oxygraph, radiograph, camograph, pyrograph, duograph and tube welding machines. Mr. F. E. Rogers will explain the operation of each machine.

Mr. W. R. Hulbert of the Metal and Thermit Corporation, will present an illustrated lecture on "Thermit Welding" including large repairs such as ship rudder posts.

Northern New York

A meeting of the Northern New York Section was held on December 17th in Edison Club Hall in conjunction with the Schenectady Section of the A. S. M. E. Mr. F. L. Morse, President of the Morse Chain Company of Ithaca, gave a very interesting and inspiring talk outlining the historical development of "Mechanical Transmission of Power" from the Egyptians to the present time. The talk was preceded by a motion picture on "The Gyroscope."

The next meeting of the Section will be held on January 8th in Schenectady at which time Mr. W. M. B. Brady and Mr. W. Remington will present a paper on "Application of Electric Arc Welding to Railway Transportation."

Cleveland

The November meeting of the Cleveland Section was held on the 20th at which time Mr. W. L. Warner of the General Electric Company, delivered a paper on "Arc Welding Pipe Lines."

Boston

The December meeting of the Boston Section was held on the 14th at the Boston City Club at 8 P. M. Mr. T. A. Wry, Chairman of the Section, spoke briefly on the welding of cast iron, particularly large turbine castings. Mr. R. L. Browne read a paper on "Thermit Welding

The question as to whether in welding heavy plate it is better to use a large electrode and high current and make a deposit in one bead or to use a small electrode and light current and make a deposit in several beads was answered by the test results of two test pieces made under the different conditions specified above and which were pulled apart.

Mr. J. W. Morrissey read Mr. Caldwell's paper on "Fluxes and Their Functions in Arc Welding."

New Members for the Months of October, November and December

BOSTON

Melvin J. Marco, Prop. Bath Welding Co., 3 Summer St., Bath, Me. C

Richard Eason, Cutter, Worthington Pump & Mchy. Co., 37 Quincy St., Sommerville Mass. D

CHICAGO

R. E. Powell, Elec. Engineer, Western Elec. Co., Inc. Dept. 2471-1 Hawthorne Sta., Chicago ..... B

Jonathan Wolfe, Asst. Supt., Track & Roadway, Chicago Surface Lines, 1165 N. Clark St., Chicago, Ill. ..... B

Arthur B. Brown, Service Welder Air Reduction Sales Co., Spirit Lake Hotel, Spirit Lake, Idaho ..... D

Walter Hackert, Welder, Albert Pick Co., 748 E. Marquette Road, Chicago, Ill. ..... D

E. Gust Johnson, Elec. & Acetylene Welder, N. Y. C. 8134 So. Justine St., Chicago, Ill. ..... D

Chas. C. Rink, Service Welder, Santa Fe Ry., 4531 S. Spaulding Ave., Chicago, Ill. ..... D

CLEVELAND

H. Gnewotta, Welder & Machinist Clevland Armature Wks., St., Clair Ave., near E. 49th St., Cleveland C

Judson E. Wolcott, Jr., Salesman The Betz-Pierce Co., 2230 E. 9th St., Cleveland, Ohio C

Robert Palmer, Welding Foreman, Nickle Plate RR., 361 Monroe St., Conneaut, Ohio ... D

LOS ANGELES

C. J. Jorgensen, Welder Gay Eng. Corp., 2650 Santa Fe Ave., Los Angeles ..... D

NEW YORK

Robt. G. Payne, Sales Mngr., Todd Twin Pole Arc Welder, 742 E. 12th St., New York, City. . B

Richard G. Sears, Partner, Sears & Bowers, Spring Garden & Fourth St., Easton, Pa. C

Geo. W. Hutchings, Elec. Welder 803 Chestnut St., Williamsbridge, New York .....D

NORTHERN NEW YORK

Wm. Kutassy, Elec. Welder, 404 Duane Ave., Shcenectady, New York .....D

Douglas MacLachlan, E le c. Welder, 7 Myrideise St., Schenectady, New York .....D

PHILADELPHIA

Arthur S. Bowers, Partner, Sears & Bowers, Spring Garden & Fourth St., Easton, Pa. C

PITTSBURGH

Edward L. Quinn, Jr. Welding Instructor, Jones & Laughlin Steel Corp. S. S. Wks. 27th & Carson Sts. Pitts. C

SAN FRANCISCO

E. R. Nash, M. M. Cousins Tractor Co. P. O. Box 674, Hanford, Cal. C

Cornelius Cardno, Boilermaker & acetylene Welder, Southern Pacific Co. 1002 Main St. Dallas Oregon .....D

SOCIETY

E. R. Lindsey, Railway Service Supervisor, Canadian Liquid Air Co. Ltd. 224 Cameron St. Moncton, New Brunswick.....B

J. G. Lincoln, Salesman, Lincoln Electric Co. 519 Free Press Bldg. Detroit, Mich. C

Arthur Geo. Hutton, Elec. Arc Welder .....D

R. S. Hutton, Director British Non-Ferrous Metals Research Association 71 Temple Row, Birmingham, England .....D

William E. Jones, Welding Demontrator, Westinghouse Elec. & Mfg. Co. 12 English Ave. Atlanta, Ga. .....D

R. Oetter, Electrician Foreman 303 Clayton St. Vineville, Macon, Ga. .....D

J. M. Parsons, Elec. Welder Letona, Ark. .....D

R. C. Redding, Elec. & Oxy-Acetylene Welder, R. C. Redding, Bacolod Occ. Negras, P. I. ....D

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EMBLEM

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Price, gold-filled, 75c., 14-K. gold, $5.00.

EMPLOYMENT SERVICE BULLETIN

Opportunities.—The Society is glad to learn of desirable opportunities from responsible sources, announcements of which will be published without charge in the Bulletin.

Services Available.—Under this heading brief announcements (not more than seventy-five words in length) will be published without charge to members. Announcements will not be repeated except upon request received after an interval of three months; during this period, names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Society's Office not later than the thirtieth of the month if publication in the following issue is desired. *ALL REPLIES should be Addressed to the Number Indicated in Each Case and Mailed to Society Headquarters.*

POSITIONS VACANT

V-14. Have opening in the Welding Division, Practice Department, requiring the services of a thoroughly experienced welder capable of supervising oxy-acetylene, electric and thermit welding in all its branches. Applicant must be highly efficient on inspecting jobs and be able to estimate time, material and method required to complete same.

V-15. Salesman. Need first-class salesman for New York territory to sell oxy-acetylene welding and cutting equipment. Must be an order getter.

SERVICES AVAILABLE

A-22. An executive and recognized authority on welding who is capable of taking charge of and develop to the fullest extent the possibilities of welding in all of its forms in an industrial organization. Affiliation as Chief Welding Engineer is desired with a large corporation in which welding can advantageously be substituted for riveting with or without possibilities which might be inherent in said corporation for salvaging costly equipment by the use of welding and thus save annually large sums of money.

A-23. Electric Welder desires position. Have completed a course on electric welding and served for five weeks on production work using automatic welding machine. Am now located in South America and desire to secure position. Have also had about five years experience on the Dominican Central Railroad along this kind of work.

A-24. First-class welder desires position. An expert welder from the Pacific Coast who has had three years of oxy-acetylene welding experience and five years of electric welding on high pressure pipe lines, dredge pipe and tank work wishes to locate in the East. Have had executive responsibility on some of the largest high pressure large diameter pipe lines built in this country and have had successful experience in welding cast iron flanges to steel pipe. Wish to locate permanently with a firm who is desirous of a competent man capable of handling both electric and oxy-acetylene welding.

A-25. First-class electric and acetylene welder with seven years experience wants steady position. Can set up own work, willing to travel, salary no option, railroad shop, shipyard and boiler shop experience.

APPLICATIONS OF OXY-ACETYLENE WELDING AND CUTTING IN THE MINING INDUSTRY*

H. ULMER†

The oxy-acetylene welding and cutting blowpipes have revolutionized plant maintenance and all old-time repair, reclamation, salvage, and production-volume standards. It would be impossible to calculate the savings daily being made directly through the application of oxy-acetylene welding and cutting, or to estimate the probable amount of the savings along these lines which could be made if every user of machinery, or any kind of metal parts, knew what is daily being accomplished by this process.

Every large manufacturer in the country has benefitted by the oxy-acetylene welding and cutting process; the great majority of them through the use of apparatus owned and operated by themselves in their own plants. Those who do not regularly have a sufficient amount of welding and cutting work to make it advisable to keep the necessary equipment on hand have their welding done by the local job welding shop. Many of these shops are owned and operated by men possessing an admirable knowledge of the scientific application of the principles of oxy-acetylene work, and are equipped to handle comparatively difficult jobs under the most favorable possible conditions.

The importance of the oxy-acetylene process to general industry is particularly well illustrated by noting its extensive adoption and wide scope of application by the coal and metal mining operators. The mining man's usage of the process for repair work in the general majority of cases is in many ways even more valuable than it is to the average manufacturer. Factories are usually situated near transportation systems and sources of supply. It is often not particularly difficult for the management of a large manufacturing plant to secure the services of an outside organization or to secure the delivery of a new part when anything serious happens to his mechanical equipment.

Not so with the mine. Mines are where you find them and develop them. Usually any facilities for the repair or replacement of metal parts are those built up at or near the mine after the mine has been developed, and the method of reclaiming out-of-service machinery must be portable, easily applied, and to be depended upon for satisfactory results. Manufacturers and plant operators are utilizing the oxy-acetylene welding and cutting process in all parts of the country to a very high degree, even though their reasons for the wide application of the process may not be quite as great as those which should impel the mechanical men in a mining organization to use this means of maintaining their plant equipment.

Not many years ago the isolated mine was dependent upon the blacksmith for repairs to operating equipment, excepting in the instances where developments justified the maintenance of a machine

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* Presented at the Nov., 1923, meeting of the Chicago Section, A. W. S.

† Service Engineer, Linde Air Products Co.

shop. The blacksmith is necessarily limited in his operations especially on heavy work, and was obliged to devise ways and means of accomplishing the results desired which often required drilling, tapping and attaching plates, bands and reinforcements when called upon to repair heavy machinery. Often his efforts resulted in a joint or a repaired part of as great strength as the original member. More frequently, however, the strength of the joint was dependent upon a forge weld with possibly incomplete union between the members, or upon the strength of a strap or a threaded connection. That the newer method of joining metal surfaces by oxy-acetylene welding is the superior of these old methods is attested by the fact that nearly every progressive blacksmith these days has equipped his shop with a welding and cutting outfit, which he uses for much of the work in which he formerly used the old, and more or less temporary methods.

Wherever the oxy-acetylene welding and cutting process is applied important savings in cost are invariably made over the cost of replacing worn or broken parts. In the mining industry there is so much heavy machinery used, and so many special machines and special pieces of equipment are required, parts for which are obtainable only from the manufacturer, that some dependable method of repairing damaged members is an absolute necessity. By welding, broken machine parts can always be placed back in service at a small part of the cost of replacement. It frequently happens that a part valued at many hundreds of dollars will be broken. In speaking of the value at this point I want to consider only the actual cost of the damaged part. For the moment we will not take into consideration the elements of replacement, or the cost of transportation from the point where the equipment is manufactured to the mine.

I know of a case where a fifteen hundred pound car loader head valued at about $900.00 was welded. It was broken in three places and was an important piece of the equipment of the mine. This casting was welded and placed back in service at a total cost less than one-tenth the cost of a new part. The savings in the replacement value of the part, however, are in most cases inconsequential when compared with the total savings to be made through the time saved. Breaking a single part may sometimes cause the shut-down of a whole plant. Frequently many men may be thrown out of employment through the fact that a comparatively small piece of equipment is out of service. In such a case the cost of any delay in the return of a part to service may be tremendous. These difficulties are accentuated by the location of most mines, far from industrial and manufacturing centers, inaccessible to transportation generally, and frequently in a section the local character of which is conducive to anything except facility in the handling heavy machinery parts. These all add to the time necessarily expended before parts can be replaced, assuming all the time that all it is necessary for the supplier to do is to put the order on the train and send it out. When special parts must be made, special castings poured to order, or where parts are ordered from a jobber or a manufacturer's agent who must order shipment forwarded, the replacement may be still further delayed.

In the mining field, as in many others, a large part of the welding work is likely to be on cast iron parts. Up to a few years ago this work was considered impracticable, principally because of the apparent difficulty in controlling the stresses and strains set up in the relatively brittle cast iron by the heat of the welding operation. Now this subject is very well understood, the practices for overcoming the results of these forces are well established. There is practically an assurance of success when these accepted practices are carefully followed out.

While on the subject of cast iron it might be a good time to mention cast iron cutting with the oxy-acetylene blowpipe. Cutting of cast iron is now being done daily all over the country, and the savings being accomplished by this operation even in the mining industry alone are enormous. This development is one of the things that have been done for industry at large through the research and experimental work carried on within the oxy-acetylene industry.

Beginners in welding are generally started off by allowing them to weld some pieces of steel together. Some authorities on welding claim this to be the easiest metal to weld, while others, who have probably gone into the subject rather deeply from a metallurgical point of view, argue that it is harder to make a perfect weld in steel than in any other metal. Anyway there is less to worry about in the way of expansion and contraction stresses in welding steel than in welding some of the other metals, and there is probably, for that reason less of the chance that even a mediocre welder will make a weld which will fail in service. The welding of steel includes work on everything from light gauge sheets to very heavy cast and forged sections, all of which is highly successful when the simple rules of applying the process are followed.

Practically all the other metals and alloys used in the mine can be welded, and most of them economically cut by the oxy-acetylene process. Aluminum, copper, brass, monel metal and others may be handled without difficulty. Scrapped metal parts may be salvaged, and returned to service, or their parts may be cut out and used in the manufacture of other pieces of equipment. In this way scrapped sheets may be used in the fabrication of small tanks and containers, gear guards, pulley idler rolls and guides and in many parts and special sections of mining machinery.

An application of welding which is now given a great deal of attention and prominence is the welding of steel and wrought iron pipe. In every application of industrial piping the oxy-acetylene welded joint has proved to be the most economical, the tightest, and altogether the most satisfactory means of joining pipe sections.

In most cases it costs less to install a welded line than a line made with screwed or other connections. As the diameter of the pipe increases the value of the saving grows. The loss of gas, for instance, through the joints of a line coupled by means other than oxy-acetylene welding generally reaches a staggering percentage of the total volume handled by the line. Where gas or air under high pressure is carried the losses increase in proportion with the pressure of the material in the pipe. With steam, oil or other materials

the losses are just as important, and the lowered pressure in a steam line due to losses in the joints may cause the wasting of a considerable amount of coal to force the pressure up to meet requirements.

Then there is an upkeep cost met with in the use of the old conventional type of pipe joints which is entirely eliminated when welded joints are used. There are no gaskets to be replaced, as with the Dresser coupling and the Van Stone flange, and there is no opportunity for corrosion of the joints as with screwed connections. In the welded line the joint is the strongest section in the line, while in all other types the joint is the weak spot. And a point that is particularly important to mining men, it costs less to insulate the welded line than any other type. In running a high pressure steam line, for instance, for a long stretch from the boilers over to a shaft head, a lot of money is spent to keep the cold out and the heat in. The difficulty and the cost of doing a presentable job of this is increased by cumbersome flanges and fittings. This is entirely overcome when welded joints are employed. The line then consists of one continuous and unbroken pipe; there are no fittings, flanges and connections to interfere.

In the Middle West a few months ago a water standpipe with welded joints was installed in a new mine shaft. This line was designed to withstand a pressure of 350 lbs. per square inch, and the welded construction was preferred primarily because of the economy of space to be effected through the elimination of flanges and connections. This welded line proved simple of installation and is giving highly satisfactory service.

Another feature I want to mention to you in connection with the welding of mine pipe work is the fabrication of headers, fittings, manifolds, bends and other accessories to the actual pipe line, and the wide variety of special equipment used in mines and mills which is made from pipe. The use of the welding process in this connection has made possible many pieces of equipment which could not be properly constructed with standard fittings and screwed connections. Apparatus formerly fabricated by these old methods is now being made by the oxy-acetylene welding process, and the result is, in every case, stronger, lighter equipment with absolutely leakproof and dependable joints.

Whether or not a mine or a mill should set apart a separate shop, equipped especially for welding, is a question that has perplexed many managers and superintendents. To one familiar with the importance of preheating and annealing, there can be only one answer. The welding shop as a distinct unit of mine, plant or mill is a comparatively small investment and one that will pay for itself over and over. Its desirability does not by any means depend upon extensive mining or milling operations, though of course, the welding shop requirements of a small plant might be very inadequate for a large one. Large or small, however, the shop should have facilities for preheating and annealing and should be so constructed that it will be as free from draughts as practicable.

In the manufacturing industry it is now pretty generally understood that plants of certain kinds are justified in providing and

maintaining well equipped shops, even though there is not enough work to keep a welder and cutter busy. It is not essential that the mine or mill welder and cutter be kept busy on repairs. There are a hundred and one things he may do when not engaged in this way. The more isolated the mine or mill from rail or water transportation, the more important becomes the welding shop as a valuable emergency and economy factor.

The reason for the permanent welding shop is twofold. In the first place it is possible to effect more dependable repairs where there are facilities for preheating and annealing, and the welds are not only sounder but actually cheaper, owing to the economy in gas consumption where welding is done on work partly heated by cheaper fuel. The second consideration is the possibility for constructive welding other than the common run of repair work. This is a matter of real importance around any mine or mill where there is proper coordination of the plant facilities. A welder who has the confidence of the plant superintendent, should be given to understand that he is expected to make recommendations wherever there is an opportunity to use the oxy-acetylene process to advantage.

Some of the more obvious applications of welding, aside from the familiar rejoining of ruptured metal in the repair of broken machine parts are: The building up of worn surface of shafts, bearings and guides, to true up the action of moving parts; building on of metal to reinforce or strengthen weak parts, such as badly worn or undersized sections or lips of buckets and scraper blades; retipping and tempering of drills and general upkeep of tools, thus speeding up work ordinarily done wholly at the forge; construction of pipe lines, either large or small, subject to adequate pressure tests; building of vats and tanks of any size; construction or repair of steel smokestacks and orebins; upkeep of rail, car and cable equipment, and the fabrication of window gratings, machinery guards and other pieces of equipment from scrap iron and pipe.

The water power turbines used at some smelters and mills are equipped with a type of water wheel with large curved "runners," or blades. Certain portions of the lower part of these runners wear away rapidly by erosion. Deep pits and irregular holes are worn in the cast iron blades from ¼ in. to 2 in. deep and over a surface of from one to three square feet. In one large smelter this difficulty is overcome by cutting out the damaged section and welding in a piece to replace it. It was found that the blades repaired in this way give excellent service, and the cost of repairing, as compared with the cost of replacing the wheels, was a negligible quantity.

A ventilating line, designed to carry air under pressure of 4 lbs. to the square inch, was built of steel sheet by welding a few months ago. This line is 4,360 ft. long and the pipe is 63 inches in diameter, all the longitudinal and circumferential seams being oxy-acetylene welded. It is evident that in fabricating steel sheet for use in a connection of this kind the means employed for making the seams must produce a strong, leakproof joint. Oxy-acetylene welding met this requirement to the highest degree.

It is obvious that there is an abundance of work around even a small mine or mill to keep an alert foreman welder occupied if he is

permitted to develop all of the possibilities for saving, both inside and outside the ordinary run of mechanical repairs. I know of one plant superintendent—connected with an eastern chemical works—who saw and seized the opportunities for welding and cutting in his establishment, and who estimates savings in excess of $150,000 in three years. A very small part of the welding and cutting work was upkeep in the usual sense. It was largely salvage and the fabrication of materials that would not have had even a scrap value in an isolated place.

The equipment and structural preparation for the small shop are very simple and comparatively inexpensive. A single urgent repair might very well justify the outlay necessary to provide such a shop. Indeed, in an extreme instance the same might be true also of the large shop. There are many instances of the kind. A notable example is the repair of a hoisting engine base at an Eastern Mine. They were using the hoisting engine for bailing water, with two 3,000 gal. tanks as bailing buckets. One day something happened, and there was an over-wind. The tank that was coming up full of water didn't stop when it should have stopped, and went right on up until it reached the sheave wheel. Here the cable snapped, and both tanks were wrecked in the sump below.

The results of this accident were tangled masses of steel cable both in the sump and above, the two wrecked tanks, minor damages to other parts of the equipment, and, most serious of all, a crack entirely across the engine bed frame. This broken bed plate was 22 ft. 3 in. in length and weighed about 20 tons.

Right after the accident they got out their cutting blowpipes and cut their way through the masses of cable, and cut the tanks and other wreckage into sizes which would be conveniently handled. Then the cutting blowpipe was used to assist in getting the engine bed out to a place where it could be welded and to prepare the members for welding.

The welding of the engine bed started on a Saturday morning, and was finished on the morning of the following Monday. And since it was welded this engine base has given service equally as satisfactory as a new part would have given.

An interesting report recently came from a mechanical engineer of a large Mexican Mining Company. This company has found the oxy-acetylene process invaluable notwithstanding the fact that oxygen delivered at the mine cost between 9 and 10 cents a cu. ft. Some of the welding jobs done at this Mexican mine were cracked bore casings of 4-in. centrifugal pumps; arms of 5½-ft. tube mill driving pulleys; teeth and small gears; welding 1-in. pipe for heating coils; joining 1-in. pipe frames for typewriter stands; welding pieces of 1½ in. foundation bolts broken off at the old thread, the bolts being set in concrete.

"This was a good job," said the mechanical engineer, speaking of the last mentioned, "for if we had not the welding apparatus we would have had to tear down 5 cu. ft. of concrete to put in new foundation bolts and would have lost at least seven days' work in the tube mill. The welding of the four bolts occupied two hours." He stated also that the company's welders have welded broken brackets

on to electric mine locomotive frames.

Descriptions like this of applications on mining machinery tells the story of welding and cutting at the mill probably better than anything else I could put before you. Many other mining executives have had experience similar to those of officials of the mines and mills I have been talking about, and I am sure that these experiences have conclusively proved to all of them the value of the oxy-acetylene process in the mining industry. Still even these men along with those who have had an opportunity to observe a great amount of welding, can profit by the results others have derived from applications of this process in the mining field.

A CHEAP, RELIABLE AND EXHAUSTIVE METHOD OF TESTING WELDED JOINTS

A. MENETRIER†

We have recently completed a series of shock bending tests which have proved of great value for an investigation of the relative strength of mild steel welded joints performed with three different types of electrodes.

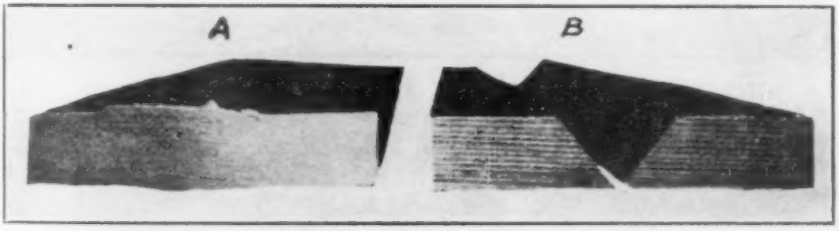

Fig. 1—A—Etched Cross Section. , B—End View

The shock bending test pieces used are 0.394″ x 0.394″ x 2.362″ (10 millimeters x 10 millimeters x 60 millimeters), with a vee weld in the center. Figs. 1 and 2 show clearly the design of the welded joints. The length of the welded strip from which the specimens were cut was sufficient to provide at least 14 specimens and in the case of one electrode 35 specimens. The width of the welded test piece from which these specimens were cut was 2.362″ (60 millimeters). The apparatus used for the tests is a Charpy pendulum single blow impact testing machine of 217 foot pounds (30 kilograms) in which the energy in foot pounds is partially absorbed in fracturing the test piece. The distance between the edges of support on which the specimen rests is 1.575″ (40 millimeters).

It is to be noted: 1st, that after welding the test joint is reduced in thickness, by planing, from ½ in. (12.7 m/m.) to 0.394″ (10 m/m.) giving test pieces of uniform section; 2nd, that the test joint is not submitted, after welding, to any treatment either thermal or mechanical.

†Welding Engineer, French Thomson Houston Co.

We have found the shock bending method of testing welded joints particularly valuable for the following reasons:

1.—A joint can be fully tested with a small expense for plate and machining.

2.—The test is very quickly done.

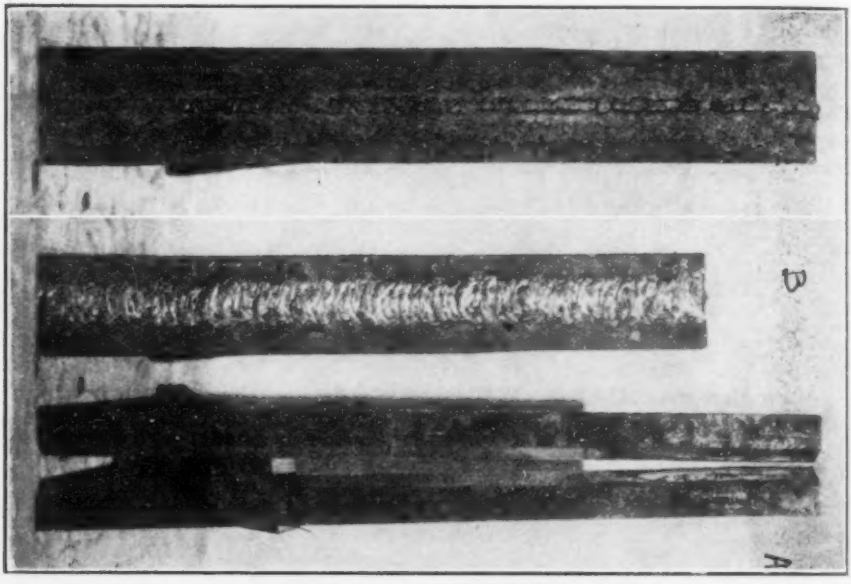

Fig. 2—Upper Figures—Rear View of Weld. Lower Figure—A—Ready to be Welded. B—Finished Weld

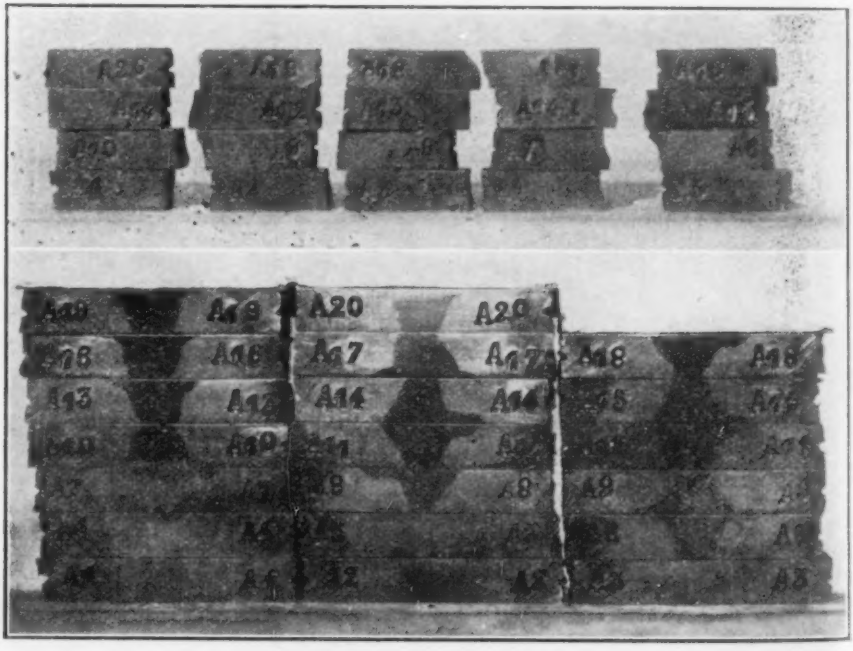

Fig. 3—Test Pieces Welded with "A" Electrode

3.—The junctions between the added metal and the base plate and also between the successive layers of weld are very severely tested.

Type A electrode was a low carbon wire dipped in lime. The weld metal with this electrode for specimens 1 to 15 was deposited in two layers. On the first layer at the bottom of the vee 175 amperes were used with an electrode of 4 millimeters in diameter (5/32″). The

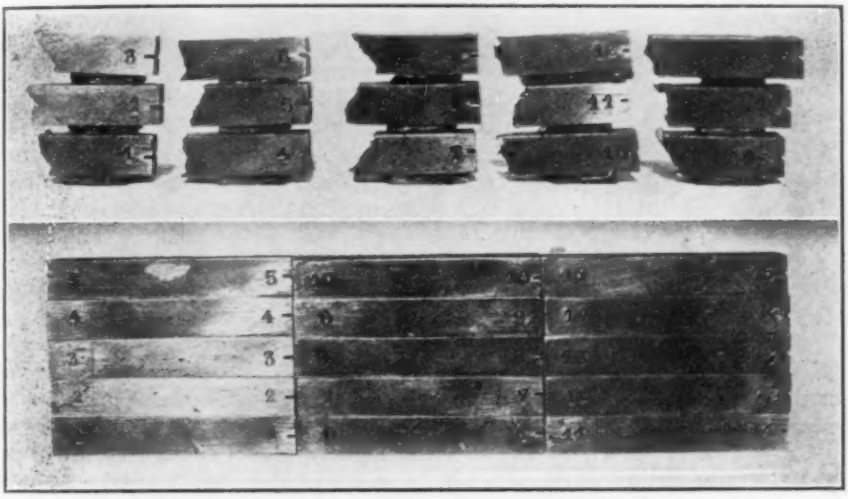

Fig. 4—Test Pieces Welded with "A" Electrode

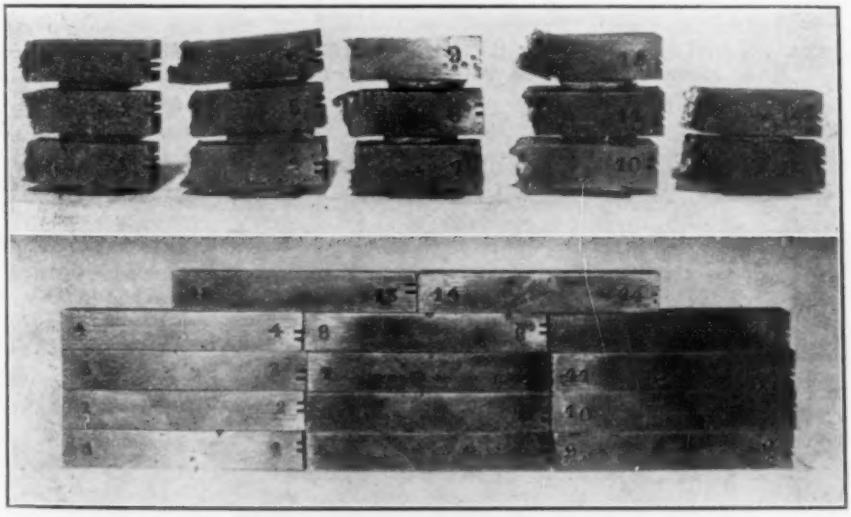

Fig. 5—Test Pieces Welded with "B" Electrode

second layer was also deposited with the same current and the same size wire. For test pieces A-1 to A-20 the welding was done in three layers. On the first layer 150 amperes were used with a 5/32″ electrode (4 millimeters). On the second and third layer 175 amperes were used with a 5 millimeter diameter electrode (slightly larger than 3/16″).

Type B was a flux coated electrode. The test pieces with this

electrode were made by depositing the metal in three layers. On the first 175 amperes were used with wire 4 millimeters in diameter (5/32″). The second and third layers were deposited with 200 amperes using a wire of 5 millimeters in diameter. (a little larger than 3/16″).

Type C was a mild steel electrode heavily coated with asbestos and saturated with certain mineral salts. The welding was done in four layers—each layer being deposited by a four millimeter diameter wire (5/32″) using 125 amperes.

AVERAGE RESULTS OF IMPACT RESISTANCE TESTS

	Blow delivered to top of vee (wide part)		Blow delivered to bottom of vee (narrow part)	
	Foot-Pounds	Kilograms	Foot-Pounds	Kilograms
Type A	15.8	2.17	6.77	0.935
Type B	30	4.15	65.0	8.95
Type C	94	12.88	67.0	9.2

The data accompanying the photographs of pieces permits one to see at a glance the impact resistance figure of each of the test-pieces.

The individual figures are far uniform but as a defective test-piece is only a local defect in the complete joint—the average figure may be taken as the characteristic of the joint. That the impact resistance figure is a true indication of the strength of the welded joint is clearly shown by the fact the high figures (as high as 144 foot-pounds (20 Kgm) correspond to a considerable bending of the test piece with junctions between added and base metal remaining unaltered whereas the low figures (as low as 4 foot-pounds (0.8 Kgm) correspond to the pieces which due to great brittleness or bad welding broke without any bending.

TABLE 1—TEST RESULTS OF ELECTRODE A

Blow given to bottom of V (narrow part)			Blow given to top of V (wide part)		
Spec. No.	Energy absorbed in fracturing test piece		Spec. No.	Energy absorbed in fracturing test piece	
	Kilograms	Food-pounds		Kilograms	Food-pounds
1	2.760	20.0	2	1.490	10.7
3	1.001	7.3	4	1.490	10.7
5	1.160	8.4	6	1.005	7.3
7	0.695	5.0	8	5.541	40.0
9	1.661	4.0	10	4.195	30.0
11	1.661	12.0	12	1.660	12.0
13	1.160	8.4	14	1.835	13.2
15	1.490	10.7	A-2	1.160	8.4
A-1	0.695	5.0	A-4	0.846	6.1
A-3	0.404	2.9	A-6	3.356	24.2
A-5	0.404	2.9	A-8	1.323	9.5
A-7	0.846	6.1	A-10	0.846	6.1
A-9	0.548	3.9	A-12	2.956	21.4
A-11	0.404	2.9	A-14	3.981	28.5
A-13	0.548	3.9	A-16	1.001	7.3
A-15	0.695	5.0	A-18	0.404	2.9
A-17	0.846	6.1	A-20	3.154	22.8
A-19	0.404	2.9			

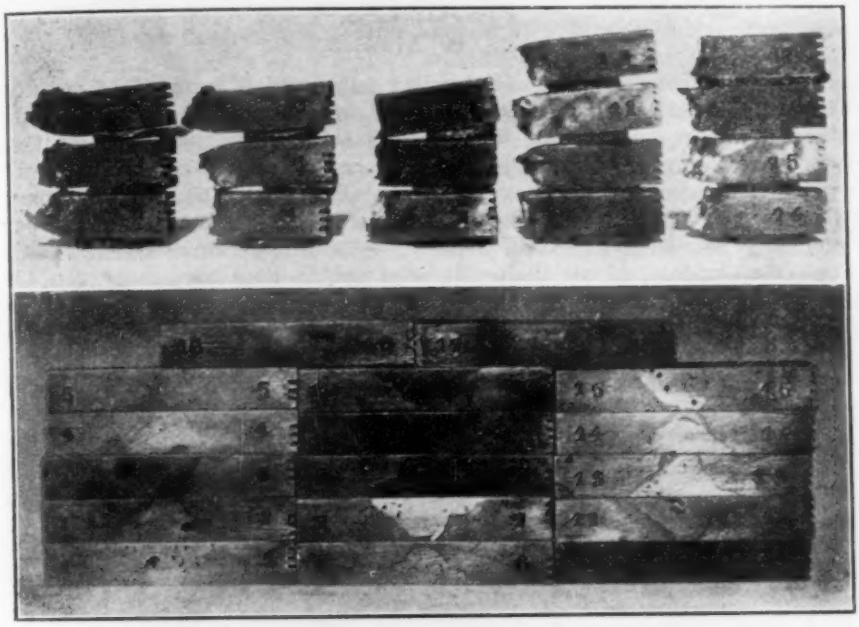

Fig. 6—Test Pieces Welded with "C" Electrode

TABLE 2—TEST RESULTS OF ELECTRODE B

Blow delivered to top of vee (wide part)			Blow delivered to bottom of vee (narrow part)		
Spec. No.	Energy absorbed in fracturing test piece		Spec. No.	Energy absorbed in fracturing test piece	
	Kilograms	Food-pounds		Kilograms	Food-pounds
1	4.885	35	2	8.490	61
3	6.249	45	4	7.979	56
5	2.194	16	6	5.310	37
7	2.760	20	8	10.860	78
9	3.154	23	10	6.011	43
11	3.356	24	12	16.042	115
13	5.541	40	14	7.979	56

TABLE 3—TEST RESULTS OF ELECTRODE C

Blow delivered to top of vee (wide part)			Blow delivered to bottom of vee (narrow part)		
Spec. No.	Energy absorbed in fracturing test piece		Spec. No.	Energy absorbed in fracturing test piece	
	Kilograms	Food-pounds		Kilograms	Foot-pounds
1	17.92	130	2	15.226	110
3	20.738	150	4	10.327	74
5	18.447	132	6	11.133	80
7	15.771	114	8	7.225	52
9	1.323	10	10	6.249	45
11	17.389	125	12	8.490	61
13	8.748	63	14	8.233	59
15	10.327	74	16	5.310	38
17	5.082	36.5			

"ONE MORE STEP IN ELECTRIC WELDING PROGRESS"*

S. W. Mann†

The welding art has so many branches and is growing so rapidly, that the expert must be a specialist. The writer is, therefore, content to follow one method and to apply himself to the promotion of that one particular branch. The electric arc method has been selected primarily because of its flexibility and wide application and economy. The writer's particular purpose here is to call attention to what can honestly be called Precision Welding—not almost correct, but within two thousandths of an inch. It was not so long ago that even the machining of a large crank shaft to two thousandths of an inch tolerance was not an easy problem, especially when its assembled or complete weight was between five and seventy-five tons. Today, however, this is the standard tolerance and is lived up to by reliable engine manufacturers.

It is now possible, through the use of precision instruments, that are capable of measuring the alignment of a shaft that is assembled in an engine frame, and the electric arc process, to repair or straighten a broken or twisted shaft or a broken casting to the same degree of strength and accuracy as that required by the manufacturer. We can, to a considerable degree, correct machining faults in large machined pieces, even after considerable use, and when age, with its normalizing influence has caused a warpage or springing of the crank shaft, due to original forging strains, we can straighten the shaft within its original tolerance at a very small cost of labor. When we say "equal to the original tolerance" we do not mean in one particular measurement, but in all of them, of which there are many on a multiple throw shaft. Its warped condition, after use and age, is produced by the natural tendency of the original forging strains to neutralize or equal one another. As a result, a shaft that might have been machined to a tolerance of one thousandth of an inch may, in the course of time, even though it be kept in storage, incur a warpage of ten to fifteen thousandths.

The classes of work coming under the head of precision jobs not only include crank shafts of steel but cast iron or cast steel as well and the term can be employed wherever a large mass of steel requires bending, straightening or twisting. The crank shaft may become twisted in various ways. It may be that the fly wheel of an engine is suddenly stopped. The inertia is liable to twist the section between the fly wheel and the crank throw or counterbalance weights, or in another instance, the cylinder may, during the course of starting the engine, come up against a water head and in that case, the inertia of the fly wheel would produce a tendency to twist the shaft. In multiple throw engines, we have on record cases of broken connecting rods or piston rods that caused sudden stopping of one particular throw and the momentum of the balance of the moving parts produced twisting in one or more places. This twisted condition can also be overcome, within certain limits, by the electric arc.

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* To be presented before Jan. meeting, Pittsburgh Section A. W. S.

† H. Kleinhaus Co.

Suppose a high pressure cast iron cylinder should have its whole flange broken off completely around the cylinder, due to a broken or loosened piston rod or water head. Although a delicate problem, it is a practicable undertaking to replace this flange on all cylinders over two feet in diameter and also to have all of its gasket face tolerance equal to the original. In undertaking work of this nature a complete practical knowledge and understanding of expansion and contraction of metals is necessary. A technical knowledge is desirable but not a necessity. The operator or supervisor must thoroughly understand the use of precision instruments, some of which he must be capable of devising himself to suit the individual problem confronting him. Low voltage is preferable, due to its limiting the possibility of burned or porous metal caused by the long arc. The welding current should not exceed 150 amperes and should be well

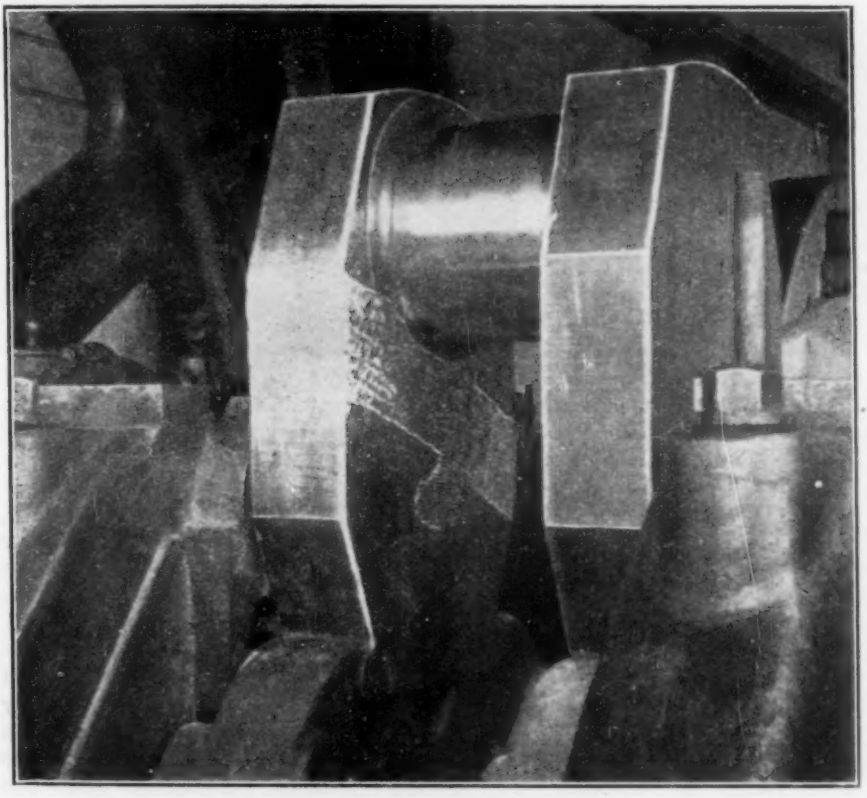

Fig. 1—Precision Welding

regulated so that it can be held constant at all times, regardless of the variations of the arc length, due to the human element. Such control of the current means that regardless of the area of the weld or puddle of molten metal under the arc, the heat per unit area of this puddle will be constant.

The process and method of repairing the crank shaft shown in the accompanying photographs can be called a Neutralized Precision

Weld and this shaft in particular, when completed, was under a tolerance of 1¼ thousandths of an inch. The process in this and similar work is briefly as follows:

The fracture, whether it lays directly in the crank pin, main shaft or web of a shaft, should be chipped off from the opposite sides, where possible. In a round section, it should be chipped to a point, leaving a "V" of approximately ninety degrees between the two pieces when they are assembled. The metal should be thoroughly clean and free from carbon pockets or shrinkage cracks before attempting to weld. The two parts are then placed together with the points of the "V" or chipped section in line with each other and with an opening between them of ⅛" or more, so that complete fusion of the added metal with either side of the "V" may be obtained.

The next step to be taken is the alignment of the work which, without question, is the most difficult problem encountered in the whole repair. Provision must be made in the original alignment for shrinkage of the metal in the primary weld tacking the two pieces together. When this alignment has been completed and the connecting weld is made, check measurements should be taken from all angles. It is often found that the shrinkage of the tacking weld is greater or less than anticipated and within reasonable limits, such errors can be corrected by the use of a peening hammer to affect an expansion, or, if contraction is required not exceeding three or four thousandths of an inch, the application of one additional layer may give the desired result. In no case should a contraction be allowed to remain in more than two layers of the original connecting weld. When the error in alignment exceeds three or four thousandths in either direction, good practice makes it necessary to chip out or break through this original weld and then start over again. The operator may have to repeat this operation many times before an absolute zero point is obtained. When this has been accomplished, the difficult part of the job is past.

The process from then on consists solely in the repeated application of single layers of metal on all sides of the weld. If desired, each layer may extend over the whole fractured surface. Shrinkage strains, which will be set up in each layer, are removed by the use of a peening tool. Additional metal must not be applied at any time until all shrinkage of the metal already deposited has been relieved, so that all indicators reach zero. It is advisable, during the application of a layer, to occasionally watch the indicators to acquaint oneself with the location and the amount of the actual stresses. By continued observation of the micrometers along with the welding, a perfect understanding of contraction can be obtained. This same observation is advisable during the peening process so that the operator may familiarize himself with the actual amount of peening required to affect a neutral weld. The understanding of contraction and expansion, as above outlined, will, in the course of a short time, enable the operator to estimate very closely the amount of peening necessary on work where the use of precision instruments is not practicable and should prove a very valuable asset to any operator.

The extent of contraction varies considerably and usually is in direct proportion to the variation in carbon in the electrode metal

As is readily understood, contraction stresses set up by a hard high carbon metal will produce more of a deflection or shrinkage than those of a soft metal, and the hard metal also requires an additional amount of peening to accomplish the neutralization. Any deflection sideways in the welding of the crank shaft may also be corrected by peening. It is absolutely essential that no more than one layer be

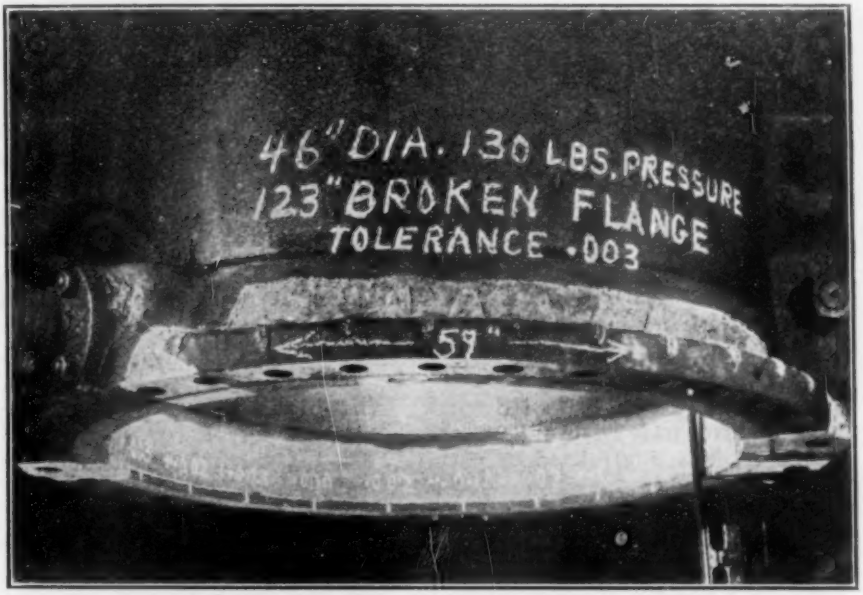

Fig. 2—Repeated Impact Testing Machine

applied over the entire surface of any precision weld before peening. It is definitely proven that the expansion produced by the minature forging blows of a pneumatic hammer do not forge the metal any deeper than ¼". The expansion of a second layer on top of a layer that has been applied without peening, will merely create additional tensile stress severe enough to probably cause an invisible fracture in the underlying layer. There are also times when, due to the thickness of a layer, along with its hardness from the use of a particularly hard metal, the contraction stresses cannot be relieved until continued peening has flaked off a certain amount of this surface of the weld. It is a fact that when a thin layer of white, hot metal is homogeneously applied to colder metal, it sets up tremendous strains, and, when applied with a thorough knowledge, can be used to accomplish desired distortions in large steel sections that cannot be obtained in any other manner. It is also acknowledged that this thin layer of metal which has tied up in itself thousands of pounds of pull created by contraction, can readily be normalized or expanded to a normal condition by the means of the forging effect of a peening hammer. Layer upon layer may be applied and treated with micrometers or indicators as gauges, with absolute confidence that, if carefully and accurately done, the finished mass of metal will be absolutely normal or neutral with neither expansion or contraction

stresses, thus doing away with the necessity for annealing.

There is also good reason to believe that the forging effect of a hammer increases the ductility and tensile strength of the metal in the same manner as the forging of steel. The full value of the peening process might be compared very favorably with steel forging, insomuch that it flattens out the individual grains of metal and produces an amalgamation between these grains, that is lacking in the original weld. It is definitely known that a grain of pure steel is surrounded by a shell of impurities. In the event of a fracture, it will follow the line if impurities between each grain and does not have to break through the center, which is the pure steel. By peening or forging, this grain is so flattened that it takes on an over-lapping layer effect and the fracture has to make its way through layer after layer of pure steel.

Not only does the peening produce an increased strength, but it makes possible a neutral weld and also the process of obtaining Precision Welding.

When it comes to cast iron welding, the welding world, as a whole, is more or less under the impression that studding of the welded areas is absolutely essential as a safety factor. In reality, where studs are applied without the peening process, they merely help to strengthen a faulty weld. We do not disapprove of studding as we have determined that it is an advantage even when employed in a neutralized or peened weld, inasmuch as it anchors the contraction of the original bounding layer, and permits a greater area of metal to be welded before peening, without danger of contraction becoming great enough to affect a fracture through the thin layer of chilled cast iron directly under the juncture line. We have, in a number of cases where we have had ample time to complete a job, welded cast iron entirely without studs, but when this process is followed, it is necessary to peen every square inch of the steel as it is applied. If this is not done, the strains set up parallel with the weld will be great enough to fracture at the juncture line. We have proven through numerous tests, that the section which usually cracks directly under the chilled area is of higher tensile strength than the actual cast iron itself, but the sheering strains set up at this point, due to the tremendous amount of contraction, is great enough to produce a fracture, even though it had a tensile strength of three or four times the original casting. In cases, where we have followed out the peening theory of one inch at a time, we have accomplished very successful welds without the use of studs, having a parting strength greater than the iron itself.

In making the above statements, it is naturally assumed that the correct welding material is used and on cast iron, there is no one or two welding wires that will satisfactorily fuse with every piece of cast iron. We might also add that the welding rod is, without question, a very important item and should be given as much consideration as the operator or the machine. In fact, successful welding may be divided into three parts of very nearly equal importance—the operator, the machine and the wire. Very often it is found that with the very best of equipment welding results are not satisfactory, due to the use of an inferior welding electrode. In another instance, the

electrode and material may be of first-class quality, and the operator is not of the interested and progressive type.

In our stock today we carry possibly six or seven different grades of wire for use on cast iron and it is usually possible to find one among this assortment that successfully gives a perfect fusion with cast iron. Castings that are older than twenty years have been found in several cases, to contain a considerable excess of phosphorus or sulphur. At times, it requires considerable experimenting to produce a counteracting chemical to overcome the detrimental effects of an excess of sulphur or phosphorus.

When one stops and really figures out the tremendous shrinkage strains set up in a cast iron weld having a cross section of five inches or more, and it is realized that most such welds have been made without provision for relieving the strains, one is not surprised that the welding of cast iron has sometimes not met with commercial success.

It is very gratifying to know that in the last three years, during which time I have directed numerous cast iron welding repairs, not a single failure has developed and this unequalled success is layed directly to the neutralizing process. This work has been done on castings having a cross section as high as ten inches and with weights running as high as ninety tons per unit. In all welding work undertaken, whether it is cast iron, steel or copper, the work has been guaranteed for a period of one year to meet all of the conditions of the original casting or forging, both as to porosity, strength and precision of alignment.

I have attempted, in this article, to show one of the numerous welding repairs that have been accomplished at a very great saving of both time and money and I know of no company today who is employing in their welding department an electric arc welder that is not receiving service many times the value of the installation.

TANKS FOR AEROPLANES FABRICATED FROM SHEET ALUMINUM BY WELDING

D. C. McGiehan

It is, of course, desirable that aeroplane parts be as light as possible, although it is necessary that they embody strength. Strength in three directions (longitudinal, vertical and transversal), however, is by no means adequate, for an aeroplane when aloft is subjected to a series of combined stresses, due to action and reaction between itself and the air. A part of a plane which comes in for at least its due amount of strain is the tank. Stresses are introduced into it by the vibration and working of the frame to which it is attached, by comparatively rapid changes in atmospheric pressure and temperature, and probably most important of all, by the slopping around of its liquid contents due to the variable positions of the plane.

Therefore, it is necessary to design and build aeroplane, gas, oil, and water circulation and expansion tanks to meet conditions which are entirely different from those to which an ordinary tank is subjected. They must be capable of carrying their contents in any position but must not permit them to change too rapidly, for this not only tends to badly strain a tank but is also apt to materially affect the equilibrium or proper control of the plane. To overcome these conditions the tank is equipped with baffle plates. These are virtually partitions which divide the inside of the tank into a number of compartments connected with each other by means of openings in the partitions. This design affords not only a reinforced tank but one in which the mobility of contents is greatly reduced.

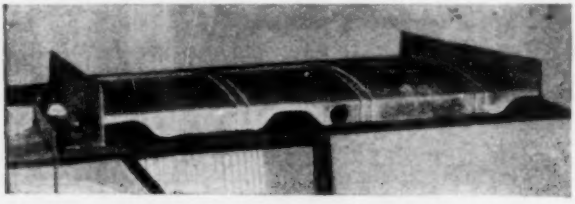

Fig. 1—Sizing Jig

Tanks embodying this principle of design are built by an aluminum welding company for the United States Government. The Government specifies the shape and outside dimensions and an aeronautical engineer employed by the company works out the details such as, thickness of material, types of joints, kind and number of baffle plates and the method of attaching these plates inside the tank.

This company usually follows a definite procedure in the fabrication of the tanks. The sheet aluminum varying in thickness from No. 22 to

Fig. 2—Building Up Edges on an Aluminum Tank

No. 16 guage, depending on size and use of tank, is first cut to size and then passed through rolls whereby ribs are rolled into the metal at specified locations, usually those where baffle plates are to be

attached. The purpose of these ribs is two-fold; first to stiffen the tank and second to provide for expansion and contraction which would otherwise distort the tank. After ribbing the material, for the body of the tank, it is bent longitudinally to the desired shape and the edges of the longitudinal seam are flanged and welded. Bending is done over wooden straight edges by the use of wooden mallets. Following the forming of the body, holes for the connections are cut and the connections welded in place. Some of these connections are patented articles.

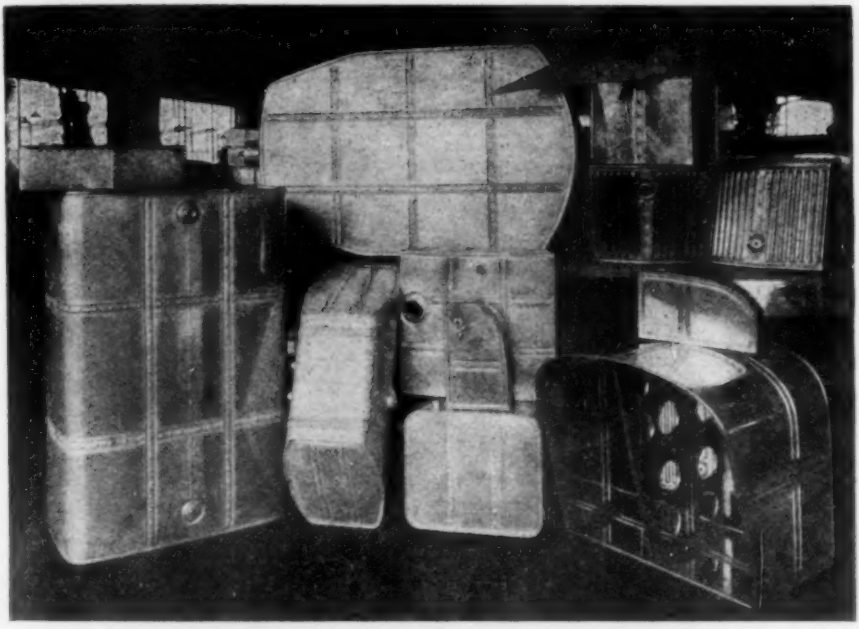

Fig. 3—Some of the Types of Tanks Manufactured—Note Diversity in Size and Shape

Next the baffle plates are cut and formed. This forming consists in flanging around the opening and edges and usually ribbing vertically through the center and around the edges. The ribs serve to stiffen the plates, as do also the flanges around the openings, while the edge flange permits pinning the baffles to the body of the tank. Next the baffle plates are put in place and holes drilled through their flanges and the body of the tank. The pins are then slipped through from the underside and slightly swaged to hold them in place. This method of securing the baffles has to be resorted to, since it is impossible to weld on the inside of these tanks because insufficient space and the obstruction caused by the baffles themselves prevent manipulation of a blowpipe. Straight riveted construction is not used, for such would prove especially inadequate in aeroplane tank fabrication because of the practical impossibility of obtaining a lasting leakproof riveted joint. The operator applies flux to the ends of the pins projecting from the tank and then directs the blowpipe flame vertically on each, in turn, melting it down and fusing it with the metal surrounding the hole, thus making an absolutely tight joint. Finally the

tank ends are flanged and welded into place. The tanks are then checked for length by inserting them between two angles bolted to a steel plate forming the table top.

In checking lengths an occasional tank is found slightly too long or too short, caused by a variation in the width of the flanges. In the former case the flanged edges are trimmed and in the latter the edges are built up. Building up is an operation in which the blowpipe is used to great advantage. To do this the tank is stood on end, a special sheet aluminum flux is painted on the welding rod, and lips located a few inches part, are built up to the required height around the edges to be lengthened. These lips establish sort of a grade line and aid the operator in increasing the flanged edges to the same width throughout the periphery of the tank.

This completes the tank with the exception of testing, which con-

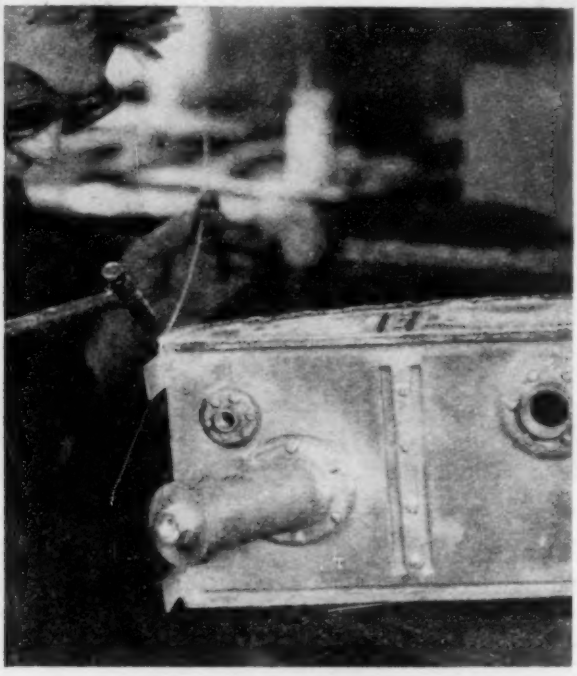

Fig. 4—Welding Edge Seams

sists in immersing each tank for one hour in a 10 per cent solution of sulphuric acid, to remove any traces of flux which may be obscuring pinholes. When taken from the acid solution the tanks are immersed for another hour in clean water to remove the acid and are then scrubbed. Next, all openings but one are plugged and each tank is held under water and subjected to a certain air pressure, depending upon its shape and thickness of metal.

Besides tanks this company also manufactures a radiator used on the Douglas Torpedo Plane. This is built of sheet aluminum and drawn aluminum tubing. The sheet is cut into squares the correct size for heads each of which is slightly dished, after which oblong holes for the tube ends are cut through it. Next the tubing is cut to

correct length and welded into the heads. To make these welds the tubing is allowed to project slightly through both heads and the welding is done from the outside.

Among the tanks manufactured for the U. S. Government are those used on the Martin Bomber, Douglas Torpedo Plane, NW Racing Plane, Navy Scout Plane, UOI-NOI Plane, Thomas Morris Scout Plane, JN-4 Training Plane, and TX Army Racing Plane. Although all these tanks are thoroughly tested by the Government after reception not one has ever been rejected. Further, "crash-proof" tanks have been built by covering these standard tanks with 2 ins. or more of live rubber and in one instance a "crash-proof" tank was filled and dropped from an altitude of 4,000 ft. It collapsed but the oxy-acetylene welded seams held and none of its contents were lost. This is certainly indicative of the strength of the welded seam. Of course, tanks are not expected to stand this rough usage, but they must be absolutely leakproof and it is in the fulfillment of this requirement that oxy-acetylene welding succeeds when other methods fail.

YOU CAN HELP THE AMERICAN WELDING SOCIETY AND INCIDENTALLY YOURSELF BY GETTING NEW MEMBERS. AN ACTIVE MEMBERSHIP DRIVE WILL SOON BE STARTED, AND YOU WILL BE REQUESTED TO SECURE ONE MEMBER OF THE SAME CLASS AS YOURSELF. LINE UP YOUR MAN NOW!

INVESTIGATION OF SEAM WELDED RAIL JOINTS*

By R. B. Fehr**

The seam welding process provides a simple, easy and economical method of permanently connecting rails. A straight, continuous, homogeneous running surface is obtained, unaffected by any excessive local heating which would tend to soften rail head metal, and thus cause "cupping." The process, furthermore, can be carried out in either old or new track, and if the track is in service, there will be no interruption to this service, as there is nothing about the process that prevents its application while the track is in use. As in all technical processes involving many factors, close attention must be paid to the fundamental principles that have been established from carefully conducted tests and practical observations.

During the past two years an intensive investigation of the seam welded rail joint has been made along the following lines:

I. Careful study of the functions of seam welded rail joints and the stresses to which they are subjected.
II. Improvements in the joint structure and welding processes.
III. Development of a practical method for making accelerated tests on seam welded joints.
IV. Comparative tests on seam welded joints in which variations have been made in either the mechanical structure or the welding process.

This investigation has now progressed to a point where some definite improvements have been made in joints subjected to repetitive impact loads and where it is believed that definite principles can be laid down. The marked improvements that have been made recently in the art of seam welding represent a definite step in advance. Further improvements will undoubtedly be made, and as soon as definite conclusions can be reached, the results will be made known, as in the present instance.

The main purpose of this article is to present the results obtained from recent comparative tests of seam welded joints, and to summarize the principles, that have been definitely established. In order to concentrate our attention on certain fundamentals regarding rail joints and to enable us to interpret more readily the test data, it may be well to summarize briefly the principal considerations that led up to our comparative tests.

GENERAL PROBLEM OF RAIL JOINTS

In considering seam welded joints it is necessary to keep in mind:

(a) The track construction.
(b) The design and preparation of the joint.
(c) The method of welding.

It is not our purpose to discuss the various kinds of track construction, but it should be emphasized that the support for the rails ought not to be so elastic as to cause excessive flexural sresses in the joints, nor so rigid as to produce a pronounced "anvil" effect, which would be harmful to both rolling stock and joints.

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* Presented at session of the Committee on Welded Rail Joints of the American Bureau of Welding and the American Electric Railway Association, Atlantic City, Oct. 10, 1923.

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The design and preparation of the joint and the method of welding it have been our chief problems. Our efforts have been devoted to the development of a joint which would not only function properly throughout the entire life of the rail, but which at the same time could be installed more easily and more economically than any other type of joint. In arriving at our conclusions as to what should constitute the best type of joint to meet such exacting requirements, we have constantly kept before us the idea that a joint must be *"balanced"* as regards its physical properties, method of installation, and cost. It is not necessary that the joint should excel in its tensile strength and its resistance to cross-bending and heavy impact loads, but it should have merely a sufficient margin of safety to resist the succession of stresses that are imposed upon it throughout the life of the rail, and at the same time it should provide a continuous, homogeneous running surface which can be easily obtained in the first place, and then maintained without further expense.

The design and preparation of the joint involves such factors as the preparation of the rail ends (under-cutting, mitering, sawing or milling); the size, shape and material of fish-plates; the use of inserts between rail ends; mutual compression of rail ends; base-plates; staggering of fish-plates; fishing surface; number and location of bolts; riveting, etc.

The method of welding the joint involves such factors as the use of grooves, bevels, or ledges in the fish-plates; the size, kind and amount of filler rod; the length and location of seams; the copper defining bar; amount of current; manipulation of filler rod and arc; rate of arc travel; order and direction of welding; size and kind of electrode; pre-heating and post-heating.

PRINCIPAL STRESSES IN SEAM WELDED JOINTS

The complex stresses in seam welded rail joints may be roughly classified as follows:

A. Compression in:
   1. Head of rail, vertical and horizontal.
   2. Fish-plate, vertical and horizontal.
   3. Seam welds, vertical and horizontal.

B. Tension in:
   1. Rail head (due to temperature drop).
   2. Rail base.
   3. Fish-plate.
   4. Seam welds.

C. Shear in:
   1. Fish-plates—vertical and horizontal
   2. Seam welds—longitudinal (due to tensile loads) and transverse (due to wedging action of fish-plates).

CAUSES OF STRESSES IN SEAM WELDED JOINTS

A. Impact, due to:
   1. Cupping, which is the result of a gap between rail ends and the cold-flow of rail head metal into this gap; and which also is the result of items 2, 3 and 4, following.
   2. Vertical compression of the metal in the rail head caused

by the wheel load, with a resultant difference in the heights of the rails at an open gap when the wheel passes over.

3. Lack of uniformity in adjacent rail sections due to variations in rolling and to poorly fitting fish-plates.
4. Improper grinding of the joint after welding. Great care should be taken that the running surface of the joint be ground to the contour of the rail and that it be perfectly straight longitudinally. If the running surface is ground flat in a cross-wise direction, it is obvious that a wheel, in passing from the normal curved contour of the rail to this flat surface, will produce impact, the very effect that careful grinding of joints is primarily intended to eliminate.
5. Corrugation in rails.
6. Flat wheels.
7. Suddenly applied rolling loads.
8. Anvil effect caused by a large mass of metal at the joint, and by too rigid support of the rail.

B. Flexure, due to:
1. Wheel loads on rail acting as a beam. Poor track foundations and excessive wheel loads cause excessive deflections and flexural stresses in the joint.

C. Temperature decrease.
1. A 100 deg. (F.) drop in temperature of the rail below that prevailing when the joint was welded induces a tensile stress of 19,500 lbs. per square inch in the rail, provided the rail ends are held in fixed positions while the temperature falls. This tensile load in the rail is transferred through the seam welds, which are put in longitudinal shear, to the fish-plates, which are thus put in tension.

D. Localized stresses set up by:
1. Expansion of heated metal.
2. Contraction of cooled metal.
3. Shrinkage of solidifying seam metal.
4. Abrupt change in the cross-section of the rail at the joint.

FATIGUE OF METALS

At this point mention should be made of the phenomenon known as "fatigue" of metals, for careful observations of joint failures have indicated that these failures are due chiefly to fatigue of the seam welds, brought about by the repeated stresses due to impact. Fatigue failure is that kind of failure which is due to alternating or repeated stresses below the ultimate strength or even below the elastic limit. Recent exhaustive researches conducted by Dr. D. J. McAdam, Jr., at the U. S. Naval Engineering Experiment Station, and by Prof. H. F. Moore at the University of Illinois, have shown that steels have an "endurance limit," which is that unit stress below which the metal can withstand an indefinitely large number of reversals or repetitions of stress without failure. It, therefore, becomes evident that the rail joint should be so designed and constructed that

it will withstand not only the stresses due to flexure, temperature decrease, welding, etc., but also the repetitions of stress due to impact, and, therefore, the unit stresses in the fish-plates and seam welds must be below the "endurance limit" in order that the joint may have an indefinitely long life.

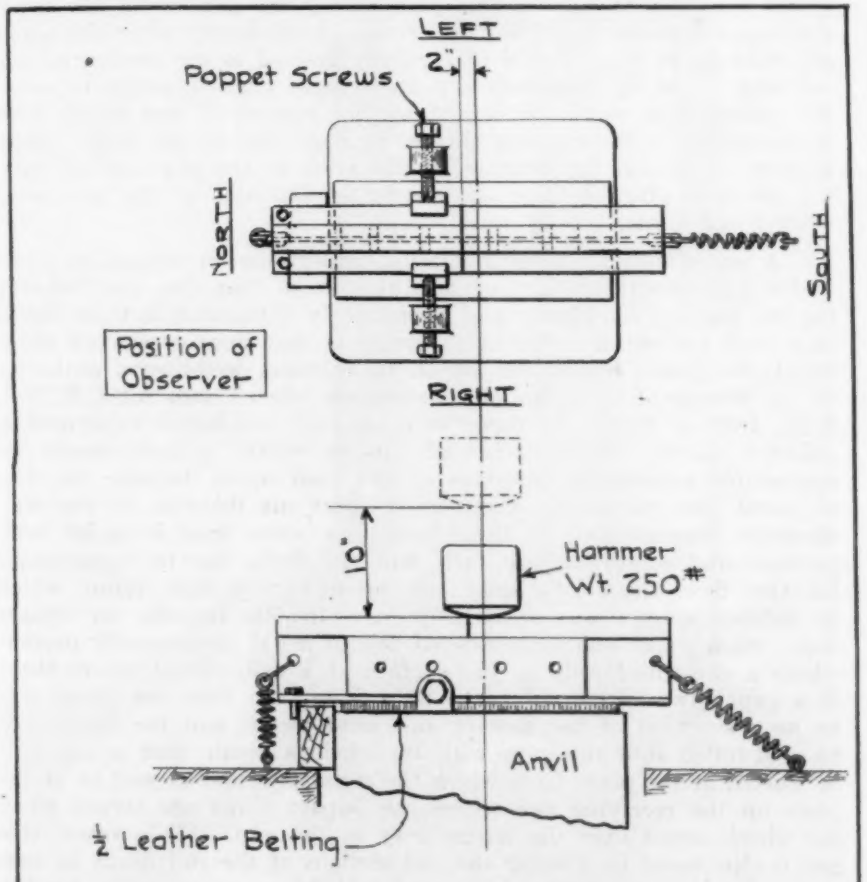

Fig. 1 Diagrammatic View of Repeated Impact Testing Machine

IMPROVEMENTS IN JOINT STRUCTURE

Having before us an outline of the stresses and their causes, we are now in a position to consider means of minimizing and resisting these stresses.

Preparation of Joint.—The most logical thing to do first is to insist that the joints be properly prepared. Reasonable and important as this idea may seem, it is surprising how often it has been neglected in actual track construction. In the first place, the gap between the

ends of the adjacent rail heads must be completely eliminated before the seams are welded. Wattman appears to have been the first engineer who thoroughly appreciated the importance of giving close attention to the preparation of the joint at the gap, and he suggested the idea of preventing cupping by bringing the rail ends together under mutual compression, thus eliminating the gap under the usual conditions encountered in actual service. Immediately after the seams are welded, the joint should be carefully ground to the contour of the rail and tested by means of a 2 ft. straight edge in order to avoid the impact that would be caused by the passing of car wheels over irregularities in the running surface or gage line of the rails. These matters of careful preparation of the joint at the gap and of careful grinding after welding are absolutely essential to the success of welded rail joints.

A sound basis for placing so much importance on setting up joints under a moderate amount of compression so that the gap between the rail heads is completely and permanently eliminated, is to be found in a very interesting series of experiments that were conducted about twenty-five years ago by the late J. B. Johnson, well-known authority on the testing of materials of construction (See Trans. A.S.C.E. Vol. XXI, 1889, p. 203). In these very carefully conducted experiments, Johnson showed that wheel loads up to 60,000 pounds caused *no* measurable permanent distortion of rail head metal, because the flow of metal was *restricted*. Contrary to previous theories, it was conclusively demonstrated in these tests that when steel is under compression and conditions are such that the metal has no opportunity for free flow, the elastic limit can reach a very high value, which in Johnson's tests was apparently over 160,000 pounds per square inch. Such conditions for restricted flow of metal are normally present where a car wheel rolls on the surface of a rail, except where there is a gap between the rail heads at a joint. In this case there will be no restriction of the flow of rail head metal, and the latter will be cold-rolled into the gap, with the obvious result that a cup will be started at the place from which the metal is rolled as well as at the place on the receiving rail where the impact blows are struck when the wheel passes over the irregularity at the gap. If, however, this gap is eliminated by placing the end sections of the rail heads in contact by means of compression, there will be no opportunity for the cold-rolling of the metal into a gap. In other words, when a car wheel passes over the joint, the condition of the rail head metal (as regards restricted flow), at what was formerly the gap will be essentially the same as that of the rest of the rail head metal, and consequently there will be no tendency for the occurrence of that most pernicious malady of joints known as cupping.

As this matter of the preparation of the joint at the gap is of such vital importance, brief descriptions will now be given of some methods which can be used for eliminating the gap.

A. *Milled rail ends*—Rail ends should be milled and slightly under-cut from the bottom of the head, with burrs and other irregularities filed off, so that the rail heads can be abutted and be in contact throughout practically the entire head sections. In

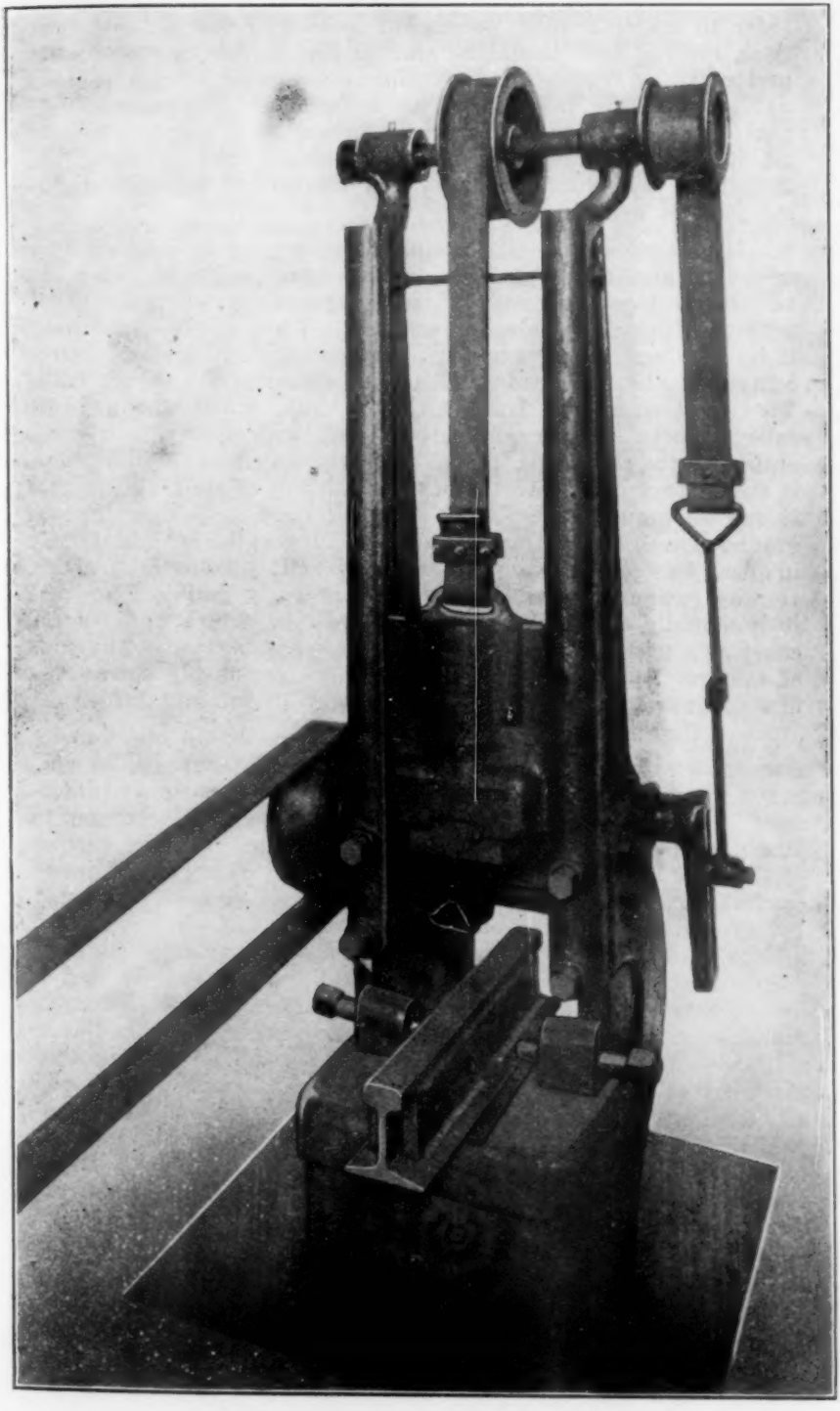

Fig. 2—Repeated Impact Testing Machine

order to insure a good, permanent contact of the rail head sections, the rail ends should be brought together under compression, preferably by the use of drift pins, which must remain in place until just before the joint is to be welded. The use of drift pins offers the great advantage of providing a simple means of maintaining the rail ends in good contact, without being disturbed by temperature changes and mechanical vibration before the joint is welded.

B. *Steel inserts*—The use of inserts should be insisted upon whenever and wherever it is found impracticable to bring the rail heads together under a moderate amount. of compression, with resulting large area of contact. When an insert is used, it is, of course, unnecessary to under-cut the rail ends to insure contact of the rail heads without interference of the rail bases. The insert should be 1/32″ to 3/32″ thick, punched from cold-rolled 0.20 to 0.30 percent carbon steel, with approximately the outline of the rail heads. When properly seated on the fish-plates, it should protrude above the head of the rail about 1/16″, so that it can be peened over flat on the rail head, and then filed or ground immediately after the welding. It should be held tightly in place between rail ends by means of drift pins as in A above. If this comparatively soft insert is properly installed so that it is actually under compression, it will be found to have the effect of a gasket, compensating for the irregularities in the ends of the rail heads, provided the latter are reasonably square (as first suggested for seam welded joints by Wattman and Jansen).

In cases where it is impracticable to place a thin insert under compression by the use of drift pins, as, for example, in connecting two sections of finished track or in placing a "dutchman" between fixed sections of rails, it is comparatively easy to obtain a tight fit, and consequently a continuous running surface of the rail, by means of a *multi-part insert*. This type of insert consists of two comparatively soft, thin, steel inserts, separated by a third and thicker one of comparatively hard steel. The middle hard steel insert and one of the softer side inserts have complementary tapers so that the middle insert can be driven down between the two soft inserts and thus produce considerable compression and a fairly uniform contact over the entire rail head section. These inserts should have profiles as described above, so that they can be peened over flat on the rail head. In case the gap opening exceeds the thickness of this triple insert, additional parallel-sided inserts of the harder grade of steel may be used to fill up the gap and thereby enable the thick tapered insert to be driven down against the other tapered insert, and thus perform its function by closing the gap tightly and permanently.

The important principle to be kept before the track and welding foreman is that the joint gaps must be eliminated, and that if the rail ends cannot be abutted or prepared to give a good area of contact when abutted, comparatively soft and medium hard steel inserts must be used to take care of irregularities in the ends of the rail and to fill the gap completely, with a resultant moderate amount of compres-

sion between rail ends to insure the permanent elimination of the gap. If the joint gaps are thus eliminated, there will be no tendency for cupping to occur, and if cupping can be eliminated, the chief cause of impact will be eliminated. As it is generally conceded that the chief cause of joint failures can be traced to repetitive impact stresses brought about by cupping, and as the seam welding process is free from the danger of causing the cupping which is due to excessive local heating and softening of the rail head metal, it is obvious that if careful attention is given to the *mechanical* preparation of the joint at the gap with a view to the elimination of the cupping which is due to open gaps, poor grinding, etc., a greatly increased life of joint will result.

In assembling the joint, care should be taken not only to eliminate the gap, but to clean the fishing surfaces with a wire brush (or with a sandblast if necessary), to remove all irregularities in the fishing surfaces, and to draw up the bolts as tightly as possible. In order to insure good fishing and sufficient initial vertical compression of the fish-plates as well as good alignment of the rails, no less than 4 bolts should ever be used.

Strengthening of joint structure.—In considering means of strengthening the joint structure, it will be of interest to determine the moment of inertia (I) and the section modulus (I/c) of the rail alone and of various sizes of fish-plates, both alone and in combination with base-plates.

TABLE I.

	Section	Moment of Inertia I	Section Modulus I/c (for base)
a.	100 lb.—6″ T-rail	48.9	17.8
b.	2—4″x1″ fish-plates, alone	9.6	5.0
c.	8½″x⅜″ base-plate with b (above)	29.1	12.8
d.	122-lb. 7″ groove rail	77.7	20.1
e.	4½″x1″, 5½″x1″ fish-plates, alone	21.3	7.7
f.	9″x⅜″ base-plate with e (above)	47.6	18.6
g.	4½″x1¼″, 5½″x1¼″ fish-plates, alone	26.7	9.6
h.	9″x⅜″ base-plate with g (above)	54.5	20.4

Table I gives values for I and I/c for two common types of rails and for various combinations of fish-plates and base-plates with these types of rails. The values of I and I/c for the rail alone were obtained from the manufacturer's data, the section modulus I/c always referring to the base, that is, to the part of the joint which is invariably in tension. In calculating the values for I and I/c it was assumed, for the sake of being on the safe side, that the fish-plates acted alone and were not aided by the head section of the abutted rails acting as an additional compression member. In other words, it was assumed that the rail heads were *not* abutted, and were, therefore, of no use as a compression member when the joint was called upon to act as a beam. The neutral axis for the calculation of I and I/c (items b, e and g) was thus assumed to pass through the center of gravity of the fish-plates. In the case of the combina-

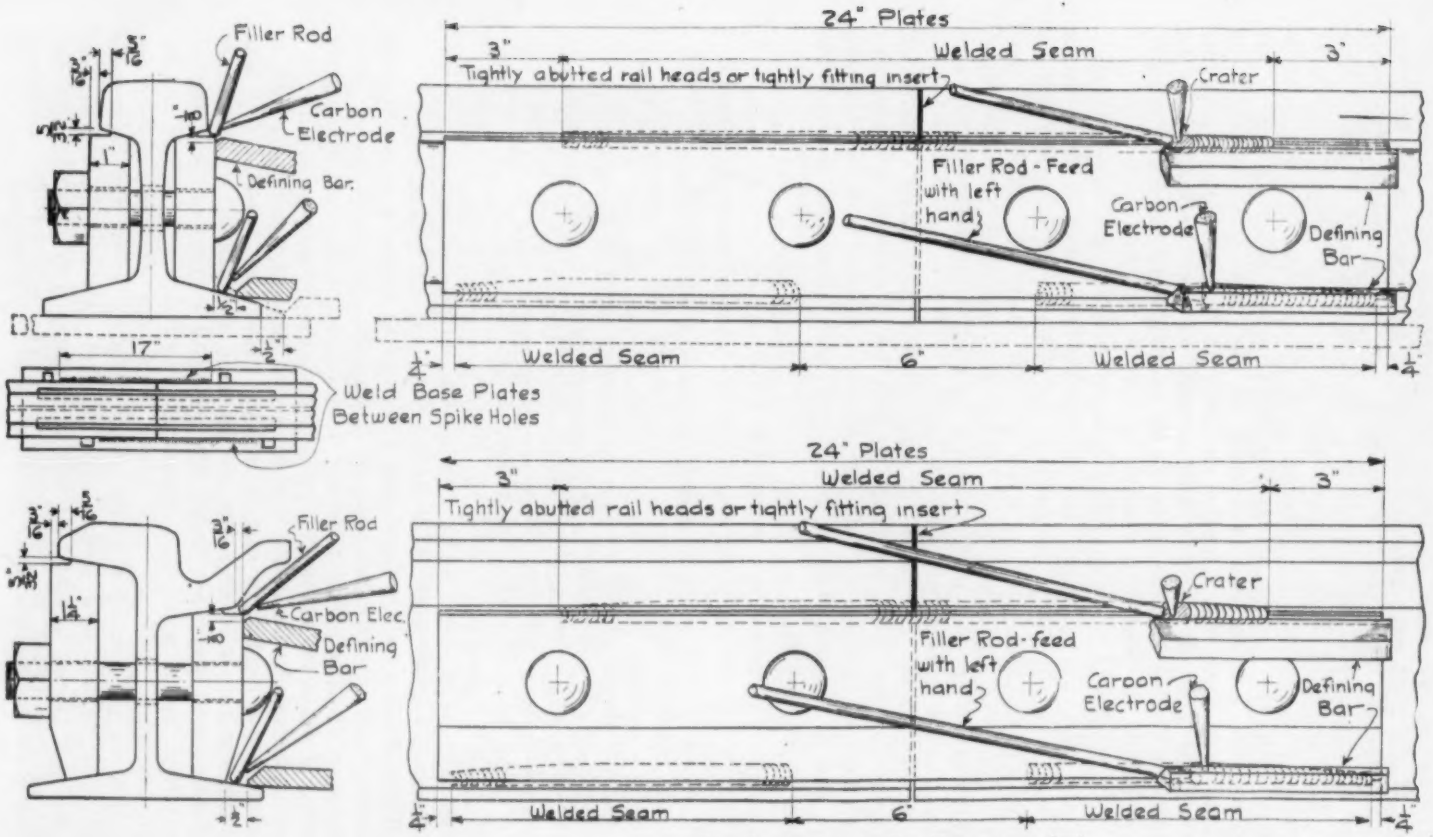

FIG 3 WELDING BY PROCESS "B"

tion of base-plates with fish-plates, as in items e, f and h, the neutral axis was assumed to pass through the center of gravity of the combination of fish-plates and base-plate, the assumption still holding that the rail heads were *not* abutted.

These values of section moduli are particularly significant because of the fact that, although the stresses due to flexure from wheel loads are never serious unless the track support is inferior or the wheel loads excessive, their combination with impact and temperature stresses (due to cold weather) may give disastrous results. Furthermore, it must be remembered that one of the results of impact is to increase the flexure stresses and, therefore, to increase the shearing stresses in the seam welds. If the joint considered as a beam is strengthened by increasing the section modulus, especially at its middle section, there will obviously be less stress set up in the seam welds with the result that the "fatigue" life of the seam welds will be increased. Consequently, there are very good reasons for providing means for minimizing the flexural stresses that may be induced in rail joints.

The section modulus of joints can be increased by three methods:

(a) Elimination of gap.
(b) Heavier fish-plates.
(c) Base-plates welded to the base of rail.

Table I shows plainly, for example, that in a T-rail joint (in which the rail heads are not abutted), a rather large unit stress can be expected in the seam welds because of the comparatively low section modulus of the fish-plates alone (5.0 as compared with 17.8). It thus becomes evident that careful preparation of the joint at the gap will not only eliminate cupping, which is the chief cause of impact, but also strengthen the joint structure as a beam and reduce the unit stresses in the seam welds by providing an additional compression member, namely, the head of the rail, which increases very materially the section modulus of the joint at its middle section over what it would be if there was a slight gap between the rail heads with only the fish-plates to withstand the impact and flexural stresses.

By the use of heavier fish-plates having sections with an economical distribution of material (that is, I or channel sections), it is reasonable to suppose that the strength and life of the joint under repetitive impact will be very greatly increased. Base-plates welded to the base of the rail acting as tension members can also be expected to increase greatly the strength and life of the joint, because the section modulus of the joint at its middle section has thus been greatly increased as shown by Table I. In order that the life of the base-plate seams may be a maximum, it is necessary that the base-plates be installed so as to have good contact with the bottom of the rail. The seam welds will then be subjected to longitudinal stresses only, rather than to additional vertical shearing stresses caused by downward pressure from the rail.

IMPROVEMENTS IN THE WELDING PROCESS

During the past year and a half a great amount of effort has been expended on the development of an improved welding process

which had for its main object the strengthening of the seam welds. Not only must the joint be designed and welded to withstand successfully the impact and flexural stresses that are imposed upon it, but it must also be welded so securely that the direct tensile and shearing stresses induced by cold weather can be resisted without a marked decrease in the "fatigue" life of the joint. Increasing the

Fig. 4—Welding by Process "A"

strength of the seam welds by adding a large quantity and better quality of seam metal is a result that has been accoplished by what may be called the "hand-feeding process," which will be referred to hereafter as Process B, as distinguished from the present Process A, in which the filler rod is laid in position. (See Figs. 3, 4 and 5). As implied by the expression "hand-feeding," the filler rod is added by hand at the discretion of the operator, who uses his other hand for controlling the carbon arc. As soon as the arc is struck, a crater is formed between the fish-plate and rail, whereupon the filler rod is slowly fed in by the operator's left hand on the side of the crater toward which the arc advances. At no time is the rod advanced in front of the arc, thus obstructing the crater and interfering with the proper deposition of metal. The idea is to maintain a clean crater of slight depth, and by a sweeping action of the arc to deposit arc-fused metal in thin layers on the receding side of the crater, while the slag and other impurities are being floated off.

In the development of this process it has been proved conclusively by means of shop tests (wedging off fish-plates, etc.), chemical

and metallographic analyses, cross-bending tests, and repeated impact tests, that a combined groove and ledge preparation of the fish-plate for the head seams gives a marked increase in the strength and life of the joint. (See Fig. 3).

Improved results are also obtained by reducing the current from 300 (as in Process A) to 200 amperes and the rate of arc travel from 4″ or 5″ per minute to 2″ to 2½″ per minute. The quantity of filler rod has been increased to 1¾″ to 2″ of 9/32″ rod per 1″ of seam weld in the middle 8″ or 10″ portion of the seam. The seam welds are tapered off toward their ends so that only 1″ of 9/32″ rod is used per 1″ of seam weld at the end of the seams, as in Process A. The spacing and length of the seams have also been investigated with results as indicated in Fig. 3. In fact, this figure may be regarded as representing the best known practice in the art of joint welding.

Fig. 5—Welding by Process "B"

Briefly summarized, the improvements effected by Process B are as follows:

(a) Much heavier, stronger, more ductile and more homogeneous seam welds are obtained.
(b) Initial seam cracks are practically unknown.
(c) The seam welds have a much longer life under repetitive impact stresses.

(d) The seam metal is more easily placed in the proper position.
(e) The arc is more easily controlled.

In addition to this "hand-feeding" Process B, some improvements have also been made by double welding, hereafter referred to as Process AA. The usual 9/32" filler rod is laid over a seam welded by Process A, and then the process is repeated. A marked improvement in the life of the seams is thus obtained, but it is not as great as that obtained by Process B, presumably because of the better quality and positioning of metal that can be obtained by "hand-feeding." It is important, however, to emphasize the fact that as a general rule Process A seams can be considerably improved by double welding, but in cases where there is poor fusion to the rail or fish-plate during the first welding operation, little improvement can be expected by double welding.

In addition to the development of an improved process for welding seams, a considerable amount of time and effort has been given to the development of a filler rod which would produce a better quality of seam metal. Considerable progress has been made along this line and it is now possible to produce seam metal of superior quality, as determined by bending and impact tests, with recently developed coated rods.

While on the subject of improvements in the welding process, it is suggested that as much joint welding as possible ought to be done during cool weather, for the tensile stresses usually produced by cold weather in a section of track in which the rail is more or less firmly imbedded, would then be very much reduced because the rail had been *fixed* in its position at a much lower temperature than would have been the case had the rails been welded and the track paved in hot weather. It is likely that it will be found entirely practicable in most cases to weld a line of track in sections of several hundred feet (depending upon the nature of the foundation and paving) during warm weather and then to connect these sections by welding during cool weather. On at least one large property this practice is being followed with marked success, while on other properties great care is taken to connect up lines of welded track, a portion of which may be held by paving, only during the cool hours of the morning, thus avoiding the very considerable expansion of free rails which occurs at mid-day under a hot sun. In all cases it is strongly recommended that the welding of joints connecting two lines of track, which are more or less fixed in position, be carried out at as low an air temperature as possible consistent with convenience and the circumstances attending that particular installation.

DECREASED WELDING STRESSES

On account of the expansion, contraction and shrinkage stresses, which are set up in all kinds of welding operations, it is important to pay considerable attention to the relief of such stresses. In general, it may be stated that the local stresses set up by carbon arc welding are of greater instensity than those produced by gas flame welding but of lower intensity than those produced by metal arc welding. The

relative sizes of the metal arc, carbon arc, and gas flame probably account for these differences. The carbon arc thus not only has the advantage of being more easily manipulated than the metal arc, but it also reduces localized stresses, and at the same time provides an opportunity for largely relieving these stresses by means of a long, flaring arc which can be easily obtained, if desired. For example, it has been found advantageous to *pre-heat* and to *post-heat*, for about fifteen seconds, the ends of all seam welds and the adjacent portions of the rail and fish-plates by means of a long arc. This is a very simple operation, care being required only to the extent that the arc must not be so short as to cause any fusion of the rail metal, nor so long as to be easily broken. The use of a stabilizer in the arc welding circuit will often be found to be of considerable advantage in this connection, and at the same time will often cause a marked improvement in arc stability during the actual welding operation.

The shrinkage of the weld metal during its solidification and subsequent cooling causes vertical tensile stresses to be set up in the fish-plates. A simple and effective means of minimizing these stresses is to bolt up the fish-plates very tightly in the first place, so that a considerable *initial vertical compressive stress* can be set up in these fish-plates by means of the wedging action of the fishing surfaces. Then, when the shrinkage of the seam metal tends to set up vertical tensile stresses in the fish-plates, these tensile stresses will first have to balance the vertical compressive stresses before they can leave any residual tensile stresses in the fish-plates.

All seam welds should be strongly *tapered* toward the outside ends so as to give a "fillet" effect at the ends of the joint. In other words, the seam welds should be heavy in the middle of the joint, and should taper off (in quantity of weld metal) toward the ends, with practically no penetration of the rail at the end of the seams. In the case of the base seams, care should always be exercised to obtain as little penetration as possible throughout the entire length of the seam weld. It is never necessary to obtain more than enough penetration to assure a good *area of fusion*, and every effort should be made to obtain this area of fusion rather than deep penetration of the rail.

Staggering the seams, top, bottom, and sides, as first suggested by Jansen, should be followed as far as practicable, so that no two seams end in the same vertical plane, thus producing a "fillet" effect when the joint acts as a beam. The head seams should not extend as far longitudinally as the base seams, and when new fish-plates are ordered, it is strongly recommended (as also first suggested by Jansen), that these plates be staggered about 2" longitudinally with respect to each other. When base-plates are used, the base-plate seams should be staggered with respect to each other, and should extend between the spike holes, which should also be staggered. See Figure 3.) It would be better, of course, not to have any spike holes in the base-plates.

Interrupting the base seams (or skipping the gap, as it is frequently referred to) was first suggested by Lincoln, and is strongly recommended for minimizing welding stresses and for retaining the maximum strength of fish-plates at that part of the joint which is

subjected to the maximum impact and flexural stresses. Very conclusive experiments, to be described later, strongly emphasize the importance of skipping the gap at the base for a distance of 2″ to 8″ depending upon the length of the fish-plates.

The *order of welding* the seam should be governed by the principle that the finished joint, when cold, will tend to be concave toward the side (or top or bottom) on which the seams were welded first.

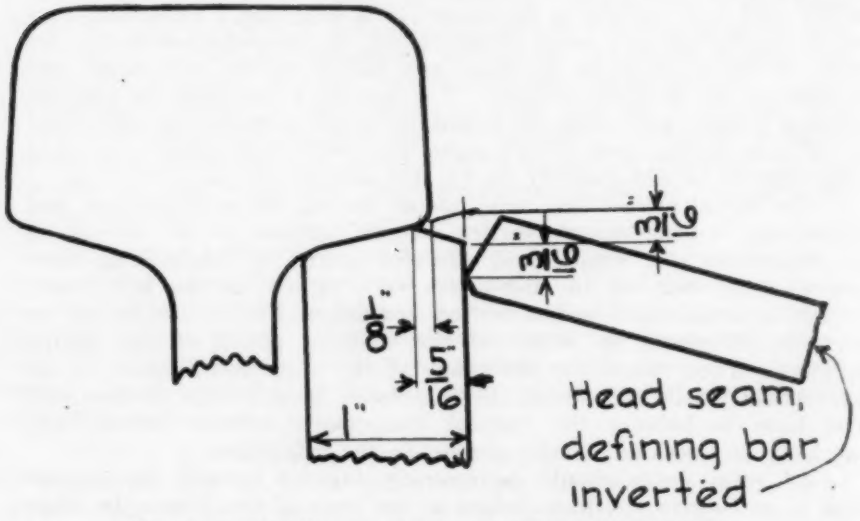

Fig. 6—Preparation for Process "AA" (Double Welding)

The aim should be to have the welded joint slightly high at the middle, that is, to have it convex rather than concave, so that by the time it has been carefully ground, it will be flat and not concave, which it would become if it were flat before grinding took place. Consequently, it will generally be found best to weld the base seams first only in those cases where the gap between the rail heads is not as tightly closed as it should be, so that the welded joint will be slightly high, instead of low, at the gap, but when the gap is properly eliminated (as should always be the case), the head seams should be welded first, thereby increasing the compression and area of contact between the rail heads. In some cases it may be desirable to weld one head seam first, then the opposite base seam, then the other head seam, and finally the other base seam. In all cases, a 2 ft. straight edge should be the guide in determining the best order of welding, for if it is found that the finished joint is usually slightly concave on top, the initial preparation of the joint and the order of welding must be so altered as to produce a slight convexity of the joint on the running surface after welding and before grinding.

ADVANTAGES OF CARBON ARC PROCESS

It will be noted that the tests described in this article deal only with carbon arc seam welding. It may be appropriate at this point to emphasize our reasons for concentrating most of our efforts on car-

bon arc welding rather than on metal arc welding of rail joints. From careful observations both in the laboratory and in the field we have concluded that the carbon arc possesses the following important advantages over the metal arc for the welding of joints:

(a) The carbon arc is more easily manipulated than the metal arc.

(b) Carbon arc welds can be obtained under conditions of rust and scale which would never produce successful results when the metal arc is used.

(c) The operator can easily see the crater formed by the carbon arc, and after a little experience can judge the amount of fusion and quality of weld obtained.

(d) Local welding stresses are not only lower in intensity, but they can be largely relieved by the simple operation of pre-heating and post-heating with a long carbon arc.

(e) Less time is required for depositing a given amount of metal.

(f) The molten seam metal can be "puddled" and thus a very good opportunity is offered for improving the quality of seam metal by the use of special fluxed filler rods.

(g) The seam metal produced by carbon arc welding is practically devoid of over-laps and oxide layers.

DEVELOPMENT OF METHOD OF TESTING JOINTS

It is one thing to make improvements in the joint structure, as determined by mechanical principles of design, and to make improvements in a welding process as determined by simple laboratory experiments and ordinary shop tests, but it is quite another thing to back up such improvements by means of tests which produce results similar to those obtained in actual service. For instance, chemical and metallographic analyses of the seam welds, wedging off fish-plates, cross-bending tests of welded joints, and compression-shear tests of seam welds, gave strong evidence of the advantages of Process B for welding joints, but it must be admitted that none of these tests gave results as regards failures which were anything like those known to occur in service. Consequently, a great deal of attention was given to the devising of a method of testing which in a comparatively short period of time would produce failures of joints similar to those which are found in actual practice.

Careful consideration of the stresses to which a seam welded joint is subjected, impressed our engineers with the thought that above all things a welded joint had to withstand repeated impact stresses, combined with the direct tensile and shearing stresses, which occur during cold weather. In fact, we went so far as to design and prepare plans for a rail joint testing machine which would put joints under a total tensile load of 200,000 lbs. (or less), and at the same time provide a means of delivering repeated blows on the joint at or near the gap. The joint was to be supported so as to give the usual beam effect.

On account of the delay that would have been caused by the building of this testing machine, it was decided to eliminate, for the

time being, the tension feature, and to utilize only the repeated impact method of testing. Accordingly, a No. 2 Automatic Drop Press of The Standard Machinery Company (Auburn, R. I.), was obtained and adapted to use as repetitive impact rail joint testing machine. Fig. 1 gives a diagrammatic arrangement of this machine and of a joint under test, while Fig. 2 is a photograph of the machine as installed. The principal data concerning this drop press are as follows:

Weight of hammer	250 lbs.
Weight of anvil	2450 lbs.
Distance between uprights	13 in.
Maximum drop	36 in.
Drop actually used in all tests	10 in.
Blows per minute (for 10 in. drop)	60

The hammer is operated by means of an automatic roller cluch, which causes the hammer to be raised to a pre-determined point. It is then suddenly released and allowed to fall freely without any retarding force except that due to friction of the guides, pulley shafts, and the small but constant force required to accelerate the comparatively small mass of the belting, pulleys and shafts. The energy delivered at each blow is thus practically constant in magnitude.

The energy of the blow, which is approximately 200 ft.-lbs., and its point of application, which is 2 inches from the gap, are based on the results obtained by McIlraith in his lead insert tests of the blow delivered by passing car wheels.

It will be noted in Fig. I that the joint is supported on a strip of ½" leather, rather than on two supports arranged to give a beam effect. Naturally, on account of the cushioning effect of the leather, there is a slight beam effect when the joint is struck by the falling weight. It was intended originally to support the joint as a beam, but limitations of space prevented us from making the necessary mechanical arrangements. However, the tests that have been conducted thus far with the arrangement as shown in Fig. 1, have been so satisfactory as regards the obtaining of comparative data on various joint structures and welding processes, that no attempt was made to support the joint as a beam for the tests reported in this article.

From the very start this repeated impact testing machine produced failures in joints which were similar to those observed in actual service, but on account of the severity of the test the seam failures occurred within a comparatively short length of time and thus enabled us to verify such improvements as we thought had been made in the structure of the joint and in the welding process, and to make still further improvements. In other words, our rail joint testing machine provided a means not only for making accelerated comparative tests but for making accelerated progress in the development of seam welded joints.

This repeated impact testing machine has been running almost continuously day and night, for many months, and a large amount of data has been obtained on many joints. Several series of tests are in progress and other series have been discontinued temporarily on account of the lack of time.

Such series of tests as permit of the drawing of definite conclusions will be presented in the following pages. At this point it should be emphasized that the outstanding features of the matters that have been brought up in the previous discussion are being corroborated by these impact tests, which,, as far as we know at present, come the nearest of any tests to producing results similar to those obtained in practice.

REPEATED IMPACT TESTS

In conducting the following series of repeated impact tests on seam welded rail joints, it was first of all recognized that on account of the large number of variables involved in welding and in fatigue testing, the results could not be expected to be as consistent as those obtained from simple tests on simple structures and processes. Every effort, however, was made to maintain all essential variables as nearly constant as possible so that the results could at least be classified as good, bad, or indifferent:

The following *general conditions* prevailed throughout the tests:

(a) All T-rail used was 6", 100 lb. ARA Standard, Type A.
(b) All grooved rail was 7", 122 lb. AEREA Standard, Class B.
(c) Fish-plates for T-rail were 24" x 1", 0.15 to .25% carbon, hot rolled steel.
(d) Fish-plates for grooved rail were 24 x 1" or 24 x 1¼" as specified in the test—the same kind of steel as in c.
(e) Base-plates for T-rail were 8" x 24" x ⅜", machine steel.
(f) Base-plates for grooved rail were 9" x 30" x ⅜", machine steel.
(g) The total length of test joint was approximately 32".
(h) Four 1-inch diameter bolts were used and were spaced 6" apart.
(i) All the bolts were removed after the joint was welded and before it was tested.
(j) Careful observations were made about once every hour. The position and length of all cracks and both seam welds and fish-plates were noted, as well as the total number of blows as indicated by a Veeder counter.

General conditions for Process A.—The regular procedure for the Standard R. W. B. Process was followed:

(a) Grade 10 filler rod 9/32" diameter was used.
(b) The fish-plates were either flush with the head of the rail or had a ⅛" to 3/16" ledge, as noted in the individual tests.
(c) Current—275 to 325 amperes.
(d) Arc length, about ½".
(e) Rate of arc travel, 4" to 6" per minute.
(f) Flux—none.
(g) Regular equipment.
(h) Same welding operator for all joints.

The general conditions for Process B were as follows:

(a) Grade 10 filler rod, 9/32" diameter (except as noted);

about 2″ of this rod were used to 1″ of welded seam.

(b) All fish-plates for Process B were provided with a combined ledge and groove, similar to that shown in Fig. 3, for the head seams.

(c) Current—200 to 250 amperes.

(d) Arc length—about ½″.

(e) Rate of arc travel—2″ per minute.

(f) Flux—none.

(g) Regular equipment, except that a special Process B light welding handle was used instead of the Regular Process A handle.

(h) The same operator welded all Process B joints up to No. 31, when he had to leave for work on the road; another operator welded all the other Process B joints.

General conditions for Process AA (double welding).—These were the same as for Process A, with the following exceptions:

(a) The fish-plates had a 3/16″ ledge combined with a slight bevel for the head seams. (See Fig. 6).

(b) The regular head seam defining bar was used for the head seams but it was turned upside down so as to provide a better dam for the seam metal. (Fig. 6).

(c) Two seams were welded by Process A, one seam on top of the other, the rod being laid in place in each case.

In all cases careful observations were made of the essential variables involved in the welding of the joints so that the repeated impact tests could be maintained on a comparative basis.

RESULTS OF REPEATED IMPACT TESTS

Tables II to VIII represent the tabulated results of the series of impact tests which have been brought to a point at which definite conclusions may be drawn.

For Table II the following explanations will serve to amplify the meanings of those columns which may not be entirely clear from a glance at the table itself.

Col. 3 refers to the process used in welding the joint:

A, for the regular process in which the filler rod is laid in place; AA, for the double welding process as previously described; and B, for the improved process in which the filler rod is fed in by hand.

Col. 4 gives the notation concerning the amount of compression between rail ends.

In the cases marked "no" it is to be understood that the rail heads were merely abutted without any compression or that there was an actual gap between the rail ends as further noted in Col. 20. In the cases marked "high" a 50-ton screw jack was employed to compress the two sections of rails, while the fish-plates were being welded. The ends of the rails were carefully milled so that a good contact area under very high compression was thus obtained.

In the cases marked "low" the mutual compression of the rail heads was purposely made comparatively low

in order to demonstrate its effect on the life of the fish-plates. The low compression was easily brought about by means of the multi-part insert, in which the middle wedge-shaped part was driven down nearly all the way with the four bolts in the joint very tightly drawn up. The middle bolts were then slightly loosened (and then tightened) so as to relieve excessive tensile stresses induced in the fish-plates by the wedging action of the tapered inserts between the rail heads, and then the middle tapered insert was driven all the way down.

Col. 5 refers to the total length of welded seams in the entire joint.

Col. 6 gives the total number of blows that occurred before the first seam crack appeared.

Col. 7 gives the location of the first seam crack.
B—for "base"; H—for "head"; N—for "north"; S—for "south".

Cols. 8, 9, 10 and 11 give the total inches of cracks in the welded seams of the fish-plates at 25,000, 50,000, 100,000 and 200,000 blows, respectively.

Cols. 12, 13, 14 and 15 refer to the seam welds of the base-plates, when they were used.

Col. 16 gives the total number of blows struck before a crack started in a fish-plate.

Col. 17 and 18 give the number of fish-plates cracked at 50,000 and 200,000 blows, respectively. The slightest sign of a crack was counted as a fish-plate failure.

Col. 19 gives the total number of blows delivered during the test. The length of the test was governed entirely by the percentage failure of the joint, the aim being to run all joints long enough so that they could be compared at 50% failure or less.

Col. 20 gives diagrammatic sketches of the joints with additional information concerning their distinguishing features.

The averages in Table II obviously include all the joints under a single group number.

The figures in parentheses represent the total number of blows, inches of seam cracks or number of cracked fish-plates, as the case may be, at the end of the tests. For example in Joint 51, the maximum number of blows was 47,600, but in Col. 9 for 50,000 blows appears the figure 79 in parenthesis (79) indicating that at 47,600 blows the total inches of seam cracks were 79 and that this figure was assumed in averaging this joint along with the others at 50,000 blows.

In Table III are found data similar to those appearing in Table II, but for the *base seams only*, in order to bring out the relative merits of Processes A, AA and B.

Table IV is similar to Table II except that it applies to 122 lb. rail only.

Table V—Col. 4 refers to the distance between the welded base

seams. The beneficial effect of skipping the gap in welding base seams on the life of the fish-plates is brought out by this table.

Table VI gives the total length of seam cracks at the end of the test and also the location of the initial seam cracks, for T-rail.

Table VII gives the same data for grooved rail. In this table the "G" refers to the grooved side; thus H G S refers to the head seam of the grooved side of the joint south of the gap. Referring back to Fig. 1, one can always determine whether or not the crack started on the side of the joint that was hit by the hammer.

Table VIII is a summary of the principal impact test data. The headings are self-explanatory except for Col. 4, "S. G. Base" which means skip-gap base, that is, the distance between welded seams as in Col. 4 of Table V. This table will be more fully explained under "Discussion of Results."

DISCUSSION OF RESULTS

In Table II joints 19 and 24 show very forcibly what may be expected when the joint has a high section modulus, for in this case the "joint" consisted of a continuous rail to which were welded 4" x 1" x 24" fish-plates as in a regular joint. In other words, there was no gap, and the section modulus was, therefore, very high, being due to both the rail and fish-plates.

The joints in Groups 3, 4 and 5 are typical of the results to be expected from Processes A, AA and B, respectively.

The joints in Group 6 indicate that with milled rail ends and very high compression, such as is obtained by means of a 50-ton screw jack, there is a comparatively small amount of seam cracking up to 50,000 blows but an excessive amount of fish-plate cracking, which is due to the fact that after the seams are welded and the pressure caused by the screw jack is released, the fish-plates must withstand the reaction due to the high compression, and they are thus put under tremendous tension. The result is that the high tensile stresses thus induced combined with the impact stresses induced by the falling 250 lb. weight cause comparatively early fatigue failure of the plate. The seam welds in the joints were undoubtedly very highly stressed in longitudinal shear, and if the plates had not failed so soon, the seam welds might have shown a comparatively early failure. It was likely, however, that the comparatively solid beam effect produced by this very high compression minimized the impact stresses with the result that the seam welds had a considerably longer life even though they were certainly under considerably higher longitudinal shear than in the cases where there was low or practically no compression of rail ends.

Joint No. 74 constituting the only one in Group 7 was included in this table along with those in Group 8, for the purpose of indicating the differences in the life of the fish-plates caused by low and high compression of the rail ends. There can be no doubt from results in Group 6 that if the rail ends are put under compression in such a way that the fish-plates are put under excessive tension after welding, the fish-plates will have a relatively short life. However, if the rail ends could be put under high compression without causing the fish-plates to be put under excessive tension, an ideal

condition would result, for the tensile stresses due to cold weather would first have to compensate the compressive stresses already in the rail and there would be a much less net tensile stress, if any, in the rail and fish-plates during cold weather. When two fixed sections of track are connected and a double wedge insert, toggle action, or other device, is employed for putting the rail ends under initial compression, the fish-plates will obviously not be required to withstand the high tensile stresses which would occur when one or both rails are free to move endwise.

Another series of tests now in progress but incomplete, and, therefore, not recorded in this article, indicate very conclusively that when drift pins are used to obtain the initial compression between rail heads, no excessive initial tensile stresses are brought about in the fish-plates, and the latter have what may be considered a normal "fatigue" life. In other words, all our repeated impact tests of joints show conclusively that the methods we have employed for making up the kind of joints which we recommend, give the best balanced results, as regards continuous, homogeneous running surface of rail, endurance of seam welds, and endurance of fish-plates.

Groups 9 and 10 illustrate forcibly the improvement in the life of seams and fish-plates that can be effected by increasing the section modulus of the joint at its middle section by means of base-plates. It is to be noted that Process B joints with base-plates were considerably better than Process A joints with base-plates, as was to have been expected from the results previously referred to. It is also to be noted that Process A joints with base-plates were better than the Process B joints without base-plates, indicating the marked improvement in the life of joints, especially 100-lb. T-rail joints, that can be brought about by the use of base-plates. This result, however should not be construed as a recommendation that Process A with base-plates should be used in preference to Process B without base-plates, for the inherent characteristics of Process B such as better arc control, more effectively positioned seam welds, heavier, stronger and more homogeneous seam welds, etc., make this process, in general, more reliable than Process "A." Furthermore, unless the welding of the base-plate seams by Process A is very carefully carried out, the base-plate seams under repeated impact would fail prematurely; and then, of course, the effectiveness of the base-plates would be lost. In this case, the Process A joints with base-plates would be inferior to Process B joints without base-plates. It is to be noted further that the base-plates in the Process A joints failed rather rapidly, whereas those in the Process B joints were practically intact at the end of a long test.

In Table III the data for the base seams of Process A, AA and B indicate that Process AA is considerably better than A, while B is still better than AA. Good results also were obtained for double welding of the head seams but the series of tests involving the double welding of the head seams is incomplete and, therefore, is not being submitted at this time. The greater reliability of Process B should always be kept in mind when making comparisons between Processes AA and B.

Table IV indicates what may be expected in welding a 122 lb. 7″ grooved rail. The fish-plates of the joints in Group 14 were 1″ thick, while those in Group 15 were 1¼″ thick. The improvements made in Group 15, namely, Process B welding, heavier fish-plates, new filler rod and the use of base plates, as distinguished from Group 14, with Process A welding, lighter fish-plates, regular filler rod and no base-plates, give a forceful argument for strengthening the joint structure and improving the welding process.

Table V shows that welding stresses in the fish-plates can be minimized by interrupting the base seam welds, that is, by skipping the gap, with the result that the fish-plates have a much longer life under repeated impact.

The totals in Table VI for T-rail indicate that the seam failures are quite equally distributed throughout all the seam welds, but that there is a tendency for the first cracks to appear in the base seams rather than in the head seams.

In Table VII for 122 lb. grooved rail, there is a marked tendency for the first cracks to appear in the head seams, when no base-plates are used; otherwise, in the base-plate seams. In all cases, there was very little cracking of the base seams of the fish-plates.

SUMMARY OF RESULTS

On account of the pioneer nature of these tests and also on account of the lack of a standard with which welded joints may be compared, it is not possible to make any definite numerical calculations of the relative merits of welded joints as regards their "fatigue" life in service. However, a rough idea may be obtained regarding the relative merits of welded joints, as tested under conditions described above, by referring to Table VIII, which is a summary of the chief results appearing in the previous tables.

In Cols. 11 to 16 an attempt has been made to place the final results of our impact tests on a numerical basis. The method adopted is subject, no doubt, to many criticisms, but it at least has the merit of classifying in a very pronounced way the various types of joints.

In determining the so-called seam efficiencies shown in this table, the total length of seam cracks (as far as any cracks could be observed externally) was subtracted from one-half the total length of seam welds, and the result divided by one-half the total length of seam welds. The seam efficiency was thus based on half the length of seam welds rather than on the total length of seam welds because of the fact that in case half the total length of seam welds should fail on one side of the gap, the joint should obviously be a total failure. Actually, however, the seam failures in the joints were quite equally distributed on both sides of the gap, as can be seen in the summary at the bottom of Table VI, but in order not to favor the joint, the worst condition was assumed, namely, that the seam failures all occurred on the same side of the gap.

It was further assumed that as soon as the fish-plate showed an initial crack, the joint was half destroyed. On this basis Cols. 13 and 14 of Table VIII show the average fish-plate efficiencies at 50,000 and 200,000 blows, respectively. The last two columns give figures which represent a rough measure of the value of the joint at 50,000

and 200,000 blows. It will be noted that each of these figures is that seam or plate efficiency figure which was the lower one at that particular number of blows, for naturally a joint could not be stronger than its weakest part. Of course, the basis of comparison was only arbitrarily assumed at 50,000 and 200,000 blows for the purpose of illustrating the method of making the comparisons and also to classify in a rather pronounced way the various classes of joints tested. At present we have no positive means of knowing whether the most important conclusions are to be drawn from the relative numbers of blows at which the initial seam cracks occur, or whether the relative efficiencies of the joints at 50,000, 100,000, 150,000 or 200,000 blows should be given the greater weight. However, it seems to be entirely safe to conclude that a joint which will develop later initial cracking of seam welds and have better efficiency at a given number of blows when subjected to the severe conditions of our repeated impact tests, will be the better joint under actual service conditions.

From the figures in Cols. 15 and 16, supplemented by the data for 100,000 blows as given in the previous tables, the following types of seam welded joints are listed in their order of merit:

Group 15—Proc. B, 122 lb. grooved, 1¼″ fish-plates, base-plates.

Group 10—Proc. B, 100 lb. T-rail, 1″ fish-plates, base-plates.

Group 9—Proc. A, 100 lb. T-rail, 1″ fish-plates, base-plates.

Group 8—Proc. B, 100 lb. T-rail, 1″ fish-plates, no base-plates.

Group 4—Proc. A & AA, 100 lb. T-rail, 1″ fish-plates, no base-plates.

Group 14—Proc. A, 122 grooved rail, 1″ fish-plates, no base-plates.

Group 3—Proc. A, 100 lb. T-rail, 1″ fish-plates, no base-plates.

As pointed out previously, the listing of Group 9 (Process A with base-plates) above Group 8 (Process B without base-plates) is not to be construed as a recommendation for the joint typified by Group 9 in preference to the joint typified by Group 8, for the reason that the greater are control and greater relibility of the welds made by Process B may often place the joints in Group B above those in Group 9.

A general view of the joints that have been tested will serve to classify them roughly into two groups: in one, the fish-plates had the shorter life, and in the other, the seam welds had the shorter life. Process B characterizes the former group, and Process A, the latter. In truth, it can be said that the welding process has been improved to such an extent that the life of the joint is now dependent upon the life of the fish-plates, rather than upon the life of seam welds, as was formerly the case; and further, that by relieving the stresses at the middle of the fish-plate and by increasing the section modulus of the joint at its middle section, the life of the joint as a whole has been greatly prolonged.

CONCLUSIONS DERIVED FROM REPEATED IMPACT TEST DATA

1. The mechanical structure of a seam welded rail joint can be strengthened and the fatigue life of the joint greatly prolonged, by

increasing the section modulus of the joint structure as follows:

(a) Elimination of the gap between rail head so as to produce the effect of an integral rail head.

(b) Heavier fish-plate sections.

(c) Base-plates welded to base of rail.

2. The seams welded by Process B are very much superior to those welded by Process A; those welded by Process AA lie between these extremes.

3. The "fatigue" life of the fish-plates is materially increased by "skipping the gap" when welding the base seams.

4. Seam cracks invariably begin at the center of the joints and progress toward the ends.

5. Repeated impact tests, such as those described in this report, produce failures of seam welded joints similar to those found in actual service, and may therefore be considered as having more value than any tests thus far devised for testing seam welded rail joints.

GENERAL SUMMARY OF PRINCIPLES

As a result of this investigation of seam welded rail joints which has been carried on in both laboratory and field, the following principles can be definitely laid down as underlying the best known practice:

1. The gap between rail heads must be completely and permanently eliminated by bringing carefully prepared rail ends together under mutual compression.

2. The strength of the joint considered as a beam must be adequate, that is, the section modulus of the joint at its middle section must be of the same order of magnitude as that of the rail.

3. The fish-plates should have not only good fishing surfaces, but also the proper shape and size of groove for the welding of the head seams.

4. The carbon content of the fish-plates ought to be between 0.25 and 0.35%.

5. The fish-plates should be drawn up very tight by means of four bolts.

6. The welding of the seam is best carried out by means of the carbon arc, using the hand-feeding process (Process B).

7. The copper defining bar is absolutely essential for obtaining the best head seam welds in the easiest and most reliable manner.

8. Pre-heatnig the ends of all seams by means of a long arc prevents excessive chilling of the weld metal and the formation of hard, brittle constituents.

9. Post-heating the ends of all seams by means of a long arc tends to relieve welding stresses.

10. Interrupting the base seams at the middle of the joint increases materially the "fatigue" life of the fish-plates.

11. Staggering and tapering the seams toward the ends of fish-plates is effective in producing a "fillet" effect at the ends of the joint.

12. Staggering the fish-plates likewise is effective in producing a "fillet" effect.

13. The order of welding seams should be such that the welded

joint after cooling is slightly high (convex) rather than flat or concave. In general, the welded joint after cooling tends to be concave toward that side, or top, or bottom, on which the seams were welded first.

14. Immediately after welding, the joint should be carefully ground to the contour of the running surface of the rail. A two-foot straight edge should allow no convexity or concavtiy. The running surface must be straight.

On account of the large number of different conditions under which seam welded joints are being installed, no attempt can be made at this time to give a standard method of installing such joints. Each set of conditions must be given indivdual study, to determine the necessary details of installation, but the final recommendations should be based upon a consideration of the foregoing principles. As soon as the fundamental principles involved in the seam welding of joints become more generally known, it is hoped that a serious attempt can be made to standardize the practice as regards rails, fish-plates, welding process and equipment, and thus effect still greater savings in the cost of rail joints. In any event, there is no doubt that seam welded joints can now be installed easily, economically and permanently, and that for all practical purposes a continuous, homegeneous, running surface of the rail can be readily obtained, and then maintained without further expense.

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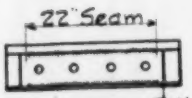
TABLE 11

Repeated Impact Test Data of Seam Welded Joints

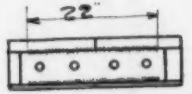
100 lb T Rail ~ Wgt. of Hammer 250 lbs ~ Drop 10 in.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Group No	Joint No	Process	Compression	Total (in) seams	Seam Cracks Started	Location 1st Crk.	Fish Plate Seam Cracks at-				Base Plate Seam Cracks at-				F. P. Cracks Started at-	No F. P. Crk'd at-		Max. Blows.	Description of Joint
							25 M	50 M	100 M	200 M	25 M	50 M	100 M	200 M		50 M	200 M		
1	19	A	Cont	88	29,000	BN	0	1.5	2	29	(Flush Fish-Plates)				——	0	0	302,000	like fig A
2	24	B	Rail	88	131,000	HS	0	0	0	4.5	(Groove in Fish-Pl.)				——	0	0	361,000	" " "
3	3	A	No	88	40,500	BN	0	4	9.5	(12)	(Flush Fish-Pl.)					0	-	138,800	like fig. B
	2	A	No	88	16,000	BN	2	5	14	(18.5)	" " "				37,800	1	(2)	127,000	
	51	A	No	88	6,000	BS	43	(79)	(79)	—	(3/16" Ledge)				——	(0)	-	47,600	
	6	A	No	80	6,500	HS	8.5	36.5	(37)	—	(Flush)				——	0	(0)	77,000	
	13	A	No	80	6,000	BS	5	7.5	11.5	(13)	(")				88,000	0	(2)	133,000	like fig. C
	52	A	No	80	5,700	BN	18	38.5	(77)	—	(3/16 ledge)				——	0	(0)	75,000	
	Av.			84	13,500		13	29	38							½		99,700	
4	60	A AA	No	80	4,300	HN BS	8	12	29	(52.5)	(3/16" Ledge)				——	0	(0)	163,000	
	63	"	No	80	37,000	BS	0	4	22.5	(41)	(" ")				——	0	(0)	134,000	like fig. D
	Av.			80	20,700	—	4	8	26	—						0	0	149,000	
5	10	B	No	88	(85,000)	—	0	0	(0)	—					52,700	0	(2)	85,000	like fig. B
	11	B	No	88	68,000	BN	0	0	2	(10.5)					82,000	0	(2)	115,000	
	16	B	No	80	16,600	BS	.5	1.3	2.5	(6)					113,500	0	(2)	160,000	like fig. C
	17	B	No	80	25,000	HS	1.5	2.5	(4)	—					72,800	0	(2)	91,500	
	AV.			84	48,700		.5	1	2.1	—					89,230	0	—	112,900	



Continuous Rail

Fig. A



Ends Abutted

Fig. B

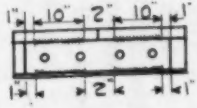


Fig. C

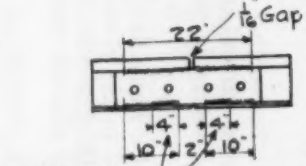


Fig. D

TABLE II (Continued)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Group No	Joint No	Process	Compression	Total (in) Seams	Seam Cracks Started	Location of Crk	Fish Plate Seam Cracks at				Base Plate Seam Cracks at-				F.-P. Cracks Started at-	No F.P. Crk'd at-		Max. Blows	Description of Joint
							25 M	50 M	100 M	200 M	25 M	50 M	100 M	200 M		50 M	200		
6	34	A	High	88	40,000	BS	.5	1	(1)	—	(3/16" Ledge)				41,000	2	—	59,000	like fig. E
	37	A	High	88	24,000	BS & BN	3	(3)	—	—	(" ")				11,500	(2)	—	43,200	" " "
	71	A	High	88	16,000	BS	1	(1)	—	—	(1/8 Ledge)				33,000	(2)	—	37,000	Fig E (triple insert)
	35	A-AA	High	88	4,300	BS	2.2	(5)	—	—	(3/16 ")				25,000	(2)	—	34,200	Fig. E. (B "Double welding on base.)
	38	A-AA	High	88	10,000	HS	(7.5)	(8)	—	—	(" ")				20,000	(2)	—	22,500	
	36	A-AA	High	84	74,000	HS	0	0	(8)	—	(" ")				74,000	0	(2)	95,000	like fig. D
	39	A-AA	High	84	34,000	HN	0	0.5	(5)	—	(" ")				68,000	0	(2)	90,000	but with 1/8"
	AV.			87	28,900		2	2.6	—	—					38,900	19/14	—	54,400	insert
7	74	A	Low	88	12,400	BS	3	5	55	(66)	3/16" Ledge				—	0	(0)	130,000	Fig E (triple insert)
8	72	B	Low	88	74,300	BN BS	0	2	3	(13)					70,000	0	(2)	142,000	like fig. F
	75	B	Low	76	68,000	BS	0	0	6	(18)					108,000	0	(2)	150,000	
	76	B	Low	76	65,000	BN BS	0	0	1.5	(27)					122,000	0	(2)	169,000	like fig. G
	77	B	Low	62	28,400	HS	0	1	13.5	(37)					91,000	0	(2)	128,000	
	78	B	Low	62	63,000	HN	0	0	14.5	(49)					(130,000)	0	(0)	130,000	like Fig. H
	AV			73	59,700		0	0.6	8	(29)					104,200	0	—	143,800	
9	8	A	No	132	4,800	BPN	0	2.5	9	(24)	35	37	44	(44)	—	0	(0)	181,000	like fig. I.
	22	A	No	132	11,200	BPS	0	0	5.5	(19)	19	19.5	37	(38)	—	0	(0)	163,000	(flush fish
	AV			132	8,000		0	1.3	7.3	(21.5)	27	28	40.5	(41)	—	0	—	172,000	plates)
10	25	B	No	132	52,000	HN	0	1.5	9.7	31	0	0	0	4	—	0	0	226,000	
	26	B	No	132	41,000	HN	0	1.7	5.5	21	0	0	0	0	200,000 over 213,000	0	1	268,000	like fig. I
	AV			132	46,300		0	1.6	7.6	26	0	0	0	2		0	1/4	247,000	

Fig E

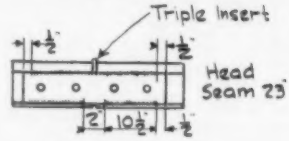


Fig F

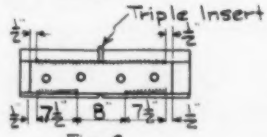


Fig G

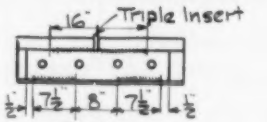


Fig H

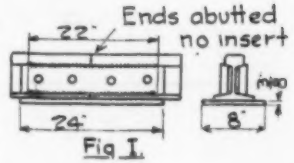


Fig I.

TABLE III

Values taken from Joints in table II, but for Base Seams only.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Group No	Joint No	Process	Compression	Total (in) Seams	Seam Crks. Started	Location 1st Crk.	Fish Plate Seam Cracks at -				Base Plate Seam Cracks at				F.-P. Cracks Started at -	No F.P. Crk'd at-		Max. Blows	Description of Joint
							25 M	50 M	100 M	200 M	25 M	50 M	100 M	200 M		50 M	200		
11	6	A	No	40	6,500	S	3	15	(15)	—						0	—	77,000	Same
	13	A	No	40	6,000	S	5	5	8.5	(11)					88,000	0	(2)	133,000	as
	52	A	No	40	5,700	N	16	21	(40)	—						0	—	75,000	Fig. C.
	Av			40	6,100		8	13.6	21	—						0	—	95,000	
12	60	AA	No	40	4,300	S	3.5	4	13	(27)						0	—	163,000	Same
	63	AA	No	40	37,000	S	0	1	9.5	(16.5)						0	—	134,000	as
	Av			40	20,700		2	2.5	11	(22)						0	—	149,000	Fig.- D.
13	10	B	No	44	(85,000)		0	0	(0)	—					52,700	0	(2)	85,000	Same as
	11	B	No	44	68,000	N	0	0	2.5	—					82,000	0	(2)	115,000	Fig. B.
	16	B	No	40	16,600	S	1	1	1.5	—					113,500	0	(1)	160,000	Same as
	17	B	No	40	63,000	N	0	0	.5	—					72,800	0	(2)	91,500	Fig C.
	Av.			42	58,200		.25	.25	1	—					80250	0	—	112,900	

TABLE IV

Repeated Impact Test Data of Seam Welded Joints

122 lb. 7" Groove Rail ~ Wgt. of Hammer 250 lbs. ~ Drop 10 in.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Group No	Joint No	Process	Compression	Total (in) Seams	Seam Cracks Started	Location 1st Crk	Fish Plate Seam Cracks at—				Base Plate Seam Cracks at				F-P Cracks Started at	No F-P Crk'd at		Max. Blows	Description of Joint
							25 M	50 M	100 M	200 M	25 M	50 M	100 M	200 M		50 M	200 M		
14	67	A	No	88	46,000	HM													like fig. J.
						HS	0	39	(39)	—	(Flush Fish-Plates)				72,100	0	(1)	84,000	
	69	A	No	88	25,000	HM	1	1.5	(7)	—	("	"	")		34,600	1	(1)	70,000	
	70	A	Low	88	5,700	HSG	1.5	(4.5)	(5)	—	("	"	")		76,400	0	(1)	80,100	like fig. J,
	73	A	Low	88	3,300	HSG	9	12	(23)	—	("	"	")		54,700	0	(1)	72,300	but has
	Av	A		88	20,000		3	14	—	—					59,450	1/8	—	76,600	triple insert
15	79	B	Low	104	1,700	BPH	0	2	3	7	9.5	13	25	25	284,000	0	0	353,000	like fig. K. (New Coated Rod Used)
					35,000	BSG													
	80	B	Low	104	22,200	BPH	0	0	0	0	1	2	6.5	16	103,000	0	1	289,000	
					229,000	HNG													
	Av			104	12,000	BP	0	1	1.5	3.5	5.3	7.5	15.3	20.5	193,500	0	1/8	321,000	
					32,000	FP													

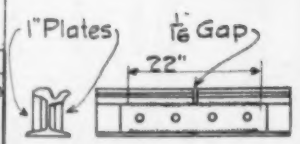


Fig. J.

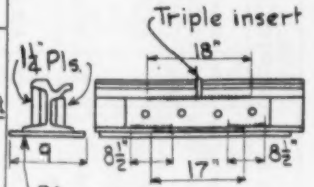


Fig. K

TABLE V

EFFECT OF INTERRUPTING BASE SEAMS ON FISH PLATE FAILURES

GROUP NO	JOINT NO	PROCESS	BASE SEAM NOT WELDED	PLATE CRACKS STARTED	TOTAL BLOWS	COMPRESSION
16	35 38	A+AA	0"	22,500	28,400	HIGH
17	36 39	A+AA	2	71,000	92,500	HIGH
18	10 11	B	0	67,400	100,000	LOW
19	16 17	B	2	93,200	125,800	LOW
20	75 76	B	8	115,000	159,000	LOW

TABLE VI 100 LB T RAIL

SEAM CRACKS AT END OF TEST.—(LOCATION OF INITIAL CRACK INDICATED BY *)

GROUP NO	JOINT NO	PROCESS	HEAD SEAMS NL	HEAD SEAMS SL	HEAD SEAMS NR	HEAD SEAMS SR	BASE SEAMS NL	BASE SEAMS SL	BASE SEAMS NR	BASE SEAMS SR	BASE PLATE SEAMS NL	BASE PLATE SEAMS SL	BASE PLATE SEAMS NR	BASE PLATE SEAMS SR	TOTAL CRACKS	MAXIMUM BLOWS
1	19	A	0*	4*	11*	9*	0*	1.5	*11	11					48	302,000
2	24	B	11*	*11	0	0	6.5	9.5	0	0					38	361,000
3	3	A	0*	0	.2	0	0	3.5	*4	3					12	138,800
	2	A	0	0	0	0	1	11	6.5	0					19	127,000
	51	A	11	11	10	3.5	11	11*	11	11					79	47,600
	6	A	11	2	0	1.5*	0	11	.5	1.5					37	77,100
	13	A	0	.5	1.3	0	1	4.5*	1.5	4					13	133,000
	52	A	11	11	11	0	11	11	11*	11					77	75,000
4	60	BASE AA	8	4	4	10*	7	10	3.5	6.5*					53	163,500
	63	AA BASE	10.5	4	3.5	7	5	4	2	5*					41	134,400
5	10	B	0	0	0	0	0	0	0	0					0	85,000
	11	B	0	0	1	0	2*	0	2.5	3.5					11	115,000
	16	B	0	0	0	0	3	2*	.5	1					6	160,000
	17	B	0	0	1.5	2*	0	0	.5	0					4	91,500
6	34	A	0	0	0	.5	0	.5*	0	0					1	59,000
	37	A	0	0	0	0	1*	0	0	2*					3	43,200
	71	A	0	0	0	0	0	0	0	1*					1	37,000
	35	AA	1	2	0	0	0	0	0	1.5*					5	34,200
	38	AA	1.5	2	2	2*	0	0	0	0					8	22,500
	36	AA	0	5*	3	0	0	0	0	0					8	95,000
	39	AA	1*	1	3	0	0	0	0	0					5	90,000
7	74	A	11	11	6	11	3	10*	3	11					66	130,000
8	72	B	0	0	11	0	0	0	1.5*	2*					15	142,000
	75	B	10	0	1	1	0	1*	1	4*					18	150,000
	76	B	1.5	0	.5	4	8*	8	0	.5*					27	169,000
	77	B	10	0	11	11*	1.5	0	3	0					37	128,000
	78	B	8	8	6*	0	8	8	8	3					49	130,000
9	8	A	0	0	6	0	2	5	2	9	11*	11	11	11	68	181,000
	22	A	0	0	5	2	.5	6	2	3	11	11*	11	5	57	163,000
10	25	B	0	11	8.5*	1.5	0	5	2.5	6	5	1	0	0	41	226,000
	26	B	0	2.5	11*	0	2	2	0	11	0	0	2	0	31	268,000
TOTALS			107	90	122	75	78	125	78	114	27	23	24	16	870	
NORTH			229				156				51					
SOUTH			165				239				39					
TOTAL FIRSTS			1	2	3	5	3	5	5	8	1	1				

TABLE VII — 122 LB. GROOVE RAIL

SEAM CRACKS AT END OF TEST (LOCATION OF INITIAL CRACKS INDICATED BY *)

GROUP NO.	JOINT NO	PROCESS	HEAD				BASE				BASE PLATE				TOTAL CRACKS	MAXIMUM BLOWS
			NG	SG	N	S	NG	SG	N	S	NG	SG	N	S		
14	67	A	6"	11"	11*	11*	0	0	0	0					39"	84,000
	69	A	0	.5	1.5*	0	1	4	0	0					7	70,000
	70	A	3	1.5*	0	0	0	0	0	0					4.5	80,100
	73	A	3	11*	7	1.5	0	0	0	0					22.5	72,300
15	79	B	2	1	0	2	0	3	1.3	0	9	0	9*	5	32.3	353,000
	80	B	3	1	0	0	0	0	0	.5	5	2	9*	3	23.5	289,000
TOTALS			17	26	19.5	14.5	1	7	1.3	.5	14	2	18	8	128.8	
NORTH			36.5				2.3				32					
SOUTH				40.5				7.5				10				
TOTAL FIRSTS			-	2	2	1	—	—	—	-	—	—	2	—		

N-North S-South G-Groove Side of Rail

TABLE VIII

Summary of Impact Test Data (Averages taken from Tables II, IV, VI and VII)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
GROUP NO	PROCESS	COMPRESSION	TOTAL IN SEAMS	SG BASE	BASE PLATE	SEAM CRACKS STARTED	SEAM CRACKS AT		NO FISH PLATES CRACKED		EFFICIENCY SEAMS AT		EFFICIENCY FISH PLATES		EFFICIENCY OF JOINTS		No OF JOINTS IN AVERAGE
							50M	200M	50M	200M	50M	200M	50M	200M	50M	200M	
1	A		88	0	NO	29,000	1.5	29	0	0	97	34	100	100	97	34	1
2	B		88	0	NO	131,000	0	4.5	0	0	100	90	100	100	100	90	1
	THE ABOVE WERE CONTINUOUS RAILS WITH WELDED FISH PLATES																
3	A	NO	84	0&2	NO	13,500	29		1/12		31		92		31		6
4	A+AA	NO	80	2	NO	20,700	8		0		80		100		80		2
5	B	NO	84	0&2	NO	48,700	1		0		98		100		98		4
6	A+AA	HIGH	87	1&0	NO	28,900	2.6		10/14		94		29		29		7
7	A	LOW	88	0	NO	12,400	5		0		89		100		89		1
8	B	LOW	73	7	NO	59,700	.6		0		98		100		98		5
9	A	NO	132	0	YES	8,000	29	(63)	0	0	56	(5)	100	(100)	56	(5)	2
10	B	NO	132	0	YES	46,500	1.6	28	0	1/4	98	58	100	75	98	58	2
14	A	NO & LOW	88	0	NO	20,000	14		1/8		68		88		68		4
15	B	LOW	104	5	YES	12,000* 132,000**	9	24	0	1/4	83	54	100	75	83	54	2

GROOVE RAIL

TOTAL NUMBER TIMES FIRST SEAM CRACK ORIGINATED IN HEAD SEAMS	16
" " " " " " " " BASE SEAMS	25
" " " " " " " " ON IMPACT SIDE OF JOINT	24
" " " " " " " " OTHER " " "	17

x First appearance of crack in Base-Plate Seams

xx " " " " " Fish-Plate Seams

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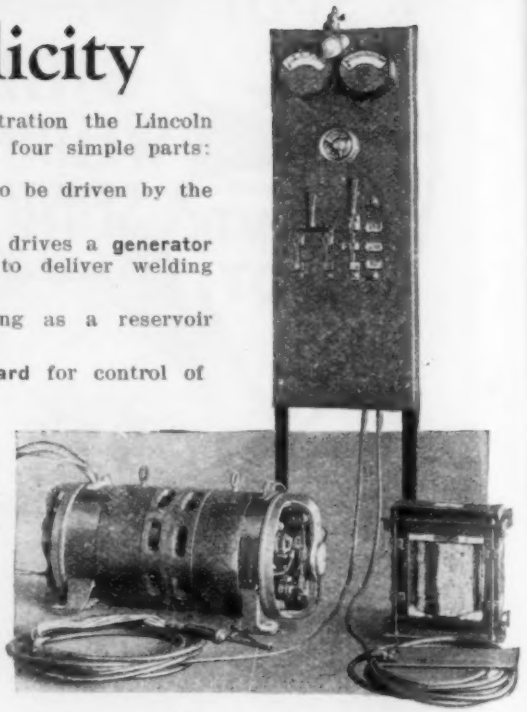

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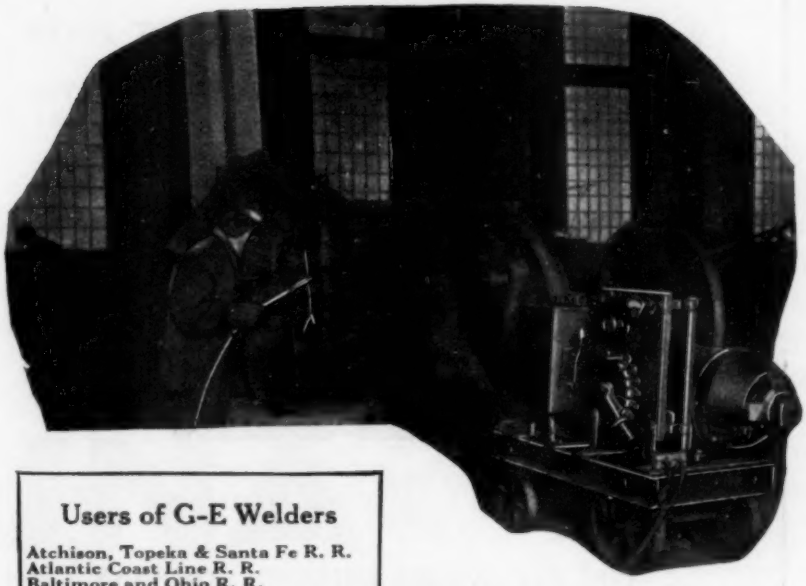

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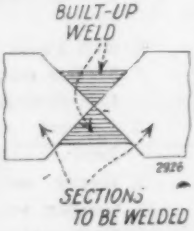

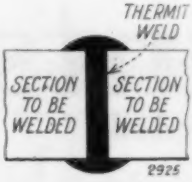

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